

# PLANNING OF SURGICAL CENTERS

Rund 1968

ERVIN PÜTSEP



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# PLANNING OF SURGICAL CENTERS BASIC STUDIES

ERVIN PÜTSEP

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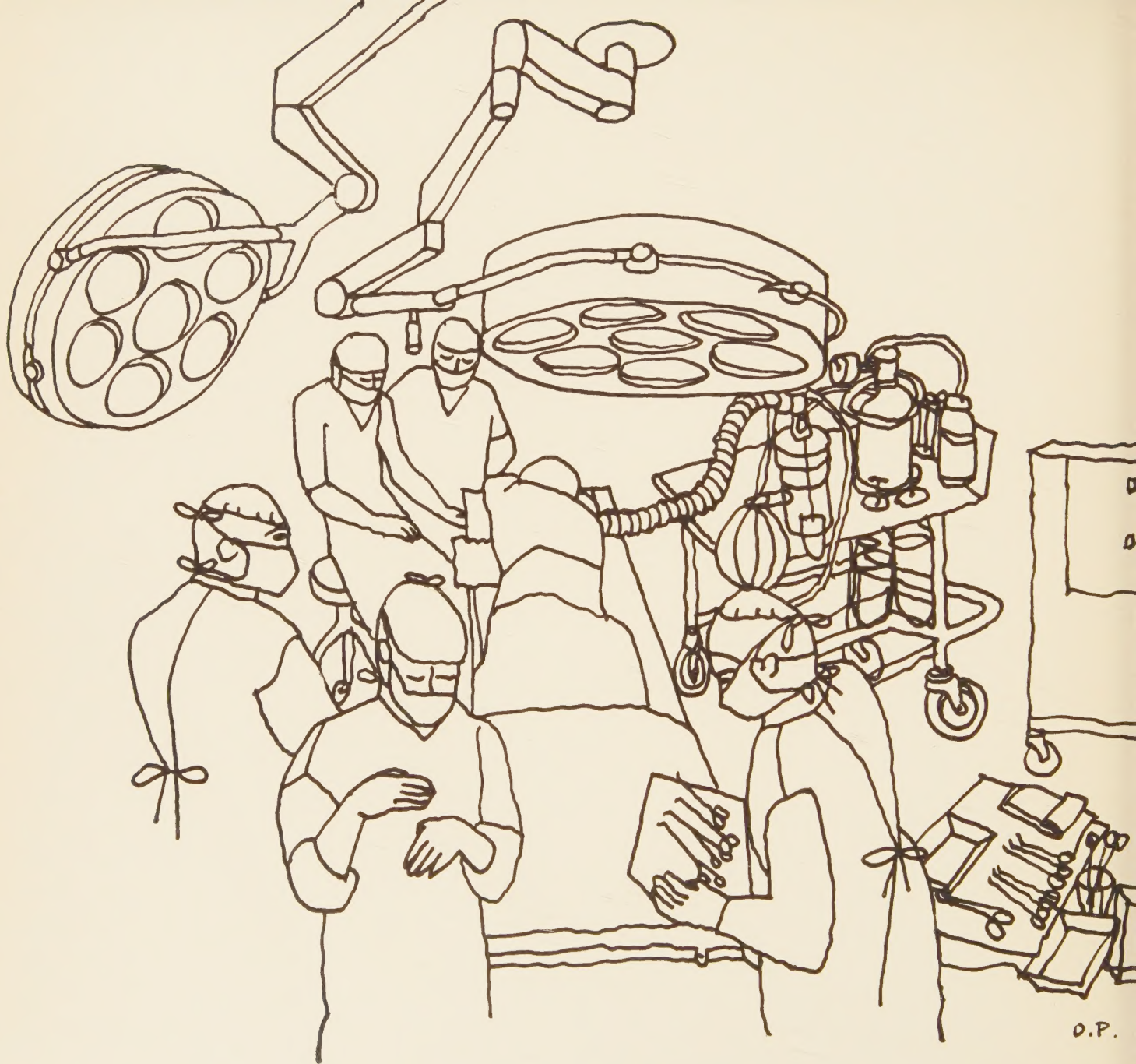
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# PLANNING OF SURGICAL CENTERS

BASIC STUDIES

ERVIN PÜTSEP

FOREWORD BY JOHN WEEKS

NATUR OCH KULTUR



*To my family*



## FOREWORD

The design of operating theatres has always been a problem which interests hospital architects. The drama of surgery, the memory of the appalling risks which were faced by patients in the pre-Listeran era, the continuing incidence of sepsis and the difficulty of isolating single causes of infection have combined to create a field of complex problems, rich in possibilities for imaginative solutions. It has happened also that as a result of the presence of powerful and colourful personalities amongst surgeons there has been the opportunity to realise, from time to time, the most extreme plans.

As development of diagnostic and therapeutic technique calls for special accommodation of increasing complexity the cost of hospital buildings is rising steadily. Surgical centres, because of the dramatic development of surgery and anaesthesia and because of the continuing risk of sepsis, have become ever more elaborate and ever more expensive, not only as a result of developing technique but as a kind of »all risk« insurance policy against obsolescence and against the invisible foe, sepsis.

One of the important characteristics of Ervin Pütsep's book is that, wherever he has found it possible, he has extracted precision from an area where imprecision is rife. An example of his rational analysis is his identification of dysfunctional influences, that is procedures where supposed aseptic requirements run counter to efficient management of operations. The implication is that aseptic surgery may depend as much on management as on the arrangement of rooms.



Accurate observation, on which this book is based, may make it possible to isolate those factors in a plan which are genuinely unique and necessary to the functions carried on there and those which are common to many other hospital functional requirements. The ability to distinguish in this way is of the greatest value. As the age/morbidity structure of populations alters, as diagnostic and therapeutic techniques of all kinds develop and change, shifts in the allocation of space within hospital buildings are increasingly often necessary for maintenance of efficiency. It is probable that planning should tend towards a hospital in which there is very little specialised space, but in which functions may be spatially reallocated with relative ease.

Surgical centres have long been regarded as the most special of special areas. It could be however that sophisticated service systems within a relatively unsophisticated structure will serve as well as the highly complex and rigid plans which have become usual. It is significant that no ideal plan is proposed in this book but points of reference of a continuous development process.

I was delighted to be asked by my friend Ervin Pütsep to contribute a foreword to his book. His studies in hospital planning have continued for many years and his knowledge of hospital users' requirements is deep. His characteristic insistence on cool thinking on the basis of intelligent observation has resulted in a most thorough and useful survey of contemporary practice and planning and wise recommendations in an area where unwise over-simplification has had far too long a run.

*John Weeks*

August 1968

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## INTRODUCTION

Although the role of the architect is generally not the one it used to be, he still feels that he has a major responsibility for a completed building.

He still has to obtain knowledge covering the whole object he is designing.

The present work is an example of an effort to accumulate facts and views needed to make decisions on fewer hands when designing a surgical center in a major hospital. Besides traditional spatial, environmental and technical needs some bacteriological aspects have been discussed as they have a particular meaning in this connection. Obviously there have been limitations. Among others the needs of less frequent specialities such as transplantation surgery and neurosurgery have not been explored.

The intention has not been to develop a rigid pattern or final plan for a surgical center, but to provide a grid against which the flow of continuously developing contributions in the planning and designing process could be correlated.

Design should aim to make the correct behaviour in a surgical center easy. Correct procedures would not be carried out if they involve a constant struggle against the physical environment.

Change and growth conduct the planning process. The processes of deliberate fragmentation on the one hand and deliberate amalgamation on the other have been inevitable.

In this study<sup>1)</sup>, which has taken a considerable time to prepare and has been frequently interrupted, I have sought in several countries the advice of surgeons, bacteriologists, anaesthetists, and nurses distinguished for their work. Their help has been extremely important to me. I also acknowledge gratefully the guidance I have received from other learned sources — too numerous to record individually.

I have drawn upon current literature and recent monographs, in the first hand American, English and Scottish, in the second Swedish, Australian and Canadian, being the main countries interested in the occurrence of post-operative wound infection and its influence on planning the surgical units. Reference to these is made in footnotes.

As Joseph D Cooper<sup>2)</sup> has stated a planner never anticipates all the conditions and problems to be encountered. As a rule the planner also cannot define and interpret correctly all the problems in an increasing complexity of life. Possibly there are gaps in communication between the planner and those of different conceptual abilities which cannot be bridged.

This is the case also with the present writer. Any errors of fact or prejudices of viewpoint are solely the responsibility of the author.

*Ervin P Pütsep*

Autumn 1968

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1) Parts of it have been published:

Pütsep Ervin P: Operating Theatre Design. in Hospital and Medical School Design. ed by George H Bell. E & S Livingstone Ltd. Edinburgh and London 1962.

Pütsep Ervin, Thorp Jan and Goldring Curt: Om operationsavdelningar. P 15. Centrala Sjukvårdsberedningen. Stockholm 1962.

Pütsep Ervin and Goldring Curt: Planung neuer Operationszentralen. in Modernes Krankenhaus. 4. Jahrbuch. Verlag für Gesamtmedizin. Berlin-Freiburg in Br. 1963.

2) Cooper Joseph D: A Nonphysician Looks at Medical Utopia. 1966, JAMA. Journal of American Medical Association 197:698.



Surgery is the highly developed branch of medical science which relates to body injuries, deformities and morbid conditions requiring remedy not by drugs alone but also by operation and the use of instruments. It may eliminate a threat to life, alleviate pain and restore or maintain the function of the normal nervous system.

Chemistry, biophysics, electronics, advanced instrumentation, computers and synthetic prosthetics, all have contributed towards development and specialization. There are already fifteen recognized surgical specialties.

The success of an operation is based on the skill of the surgeon. The operating tools and theatre equipment cannot substitute for the surgeon's skill, but they, as good planning, contribute to it.

The therapy that benefits the patient results from the action of the surgical team. The execution of modern surgical technique requires a calm, unexcitable temperament, for the stresses are many. It is therefore essential to eliminate all frustrations which may lead to errors of judgement and performance.

For the patient's welfare, environment — the interpersonal relationship within the surgical center and particularly in the operating theatre — has been found to be extremely important<sup>1)</sup>. Here often the dominant feature is the personal sharing of an acutely dangerous therapeutic experience.

The tension in the operating rooms is not due to the patient or to any necessary worry about the patient or surgery itself. The cause is the nature of the working relationship — which is authoritarian-hierarchic — between the surgeon and his staff, plus fatigue<sup>2)</sup>. Thus the need for harmony is paramount.

As prolonged operations tend to become more common, the provision of suitable environmental conditions for the surgery cannot be overemphasized. Still, the surgical center is only the stage.

Most of the processes and conditions in connection with surgery contribute to the straightforwardness of the surgical procedure and thus are functional. These procedures should be carried out in a way that gives insurance against the patient suffering damage beyond that of the actual procedure, and therefore considerate operative technique, meticulous hemostases and accurate nondevitalizing reapproximation of tissues should be maintained.

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1) Oremland J: A Psychiatrist Sits in the Operating Room. in Hospitals and Patient Dissatisfaction. ed by R H Bloom. California Medical Association. San Francisco 1958.

2) Bloom R H: The Management of the Doctor-Patient Relationship. McGraw-Hill Book Co. New York 1960, p. 250.

The *basic medical functional procedures* encircling the act of surgery are as a rule the following:

- reception and identification of patient
- transfer of patient to operating table and positioning
- anaesthetising
- intubation
- the surgical act: OPERATION
- X-ray diagnosis
- introduction of blood, sterile parenteral solutions etc.
- extubation
- transfer of patient from operating table to postanaesthetic area
- checking and supervision of patient.

The *supporting functional procedures* are *technical, organisational, administrative and clerical*: laying out and checking or re-checking the number of instruments and dressings; requisition of patient; supervision; distribution of messages; preparation of operating list, duty schedules and rota; staff paging; typing of records of operation; notification to wards of time for transport of patient to the surgical center; requisition of records, equipment and material; contacts with other departments, laboratories, workshops and suppliers; preparing the records of operations; preparing the theatre records; statistical interpretation of results of surgery; filing, photography; sketching and television; *cleaning*; cleaning of the theatre, collection of used instruments, collection of used materials, surgical garments, dressings and underlays, incineration of refuse; *storekeeping* and *repairs*.

Attention is to be paid to the questions connected to postoperative wound infections. Although diminished to a small percentage of their former proportions, the harm done still seems in general estimations to be considerable.

In the United States<sup>3)</sup> over one million postoperative infections occur yearly in 15 million individuals undergoing surgical procedures. A conventional operating room is said<sup>4)</sup> to produce an average mortality rate of about 1.6 per cent because of postoperative infections alone.

The cost of postoperative sepsis to the British National Health Service has been estimated at some \$ 15 million per annum, quite apart from the loss of life <sup>5)</sup>.

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3) Goddard James L: Study of today's changing hospital environment shows new direction for infection control. 1965, Hospital 39:19.

4) Marsh R C: Adaptability of Laminar Air Flow for Contamination Control. Conference on Clean Room Specifications. SCR-652, Office of Technical Services, Dept. of Commerce, Washington DC, May 1963.

5) Barber Mary: Hospital infection yesterday and today. 1961, Journal of Clinical Pathology 14:1:9.

The cost of medicaments alone in connection with a staphylococcus patient in Sweden is 15 to 20 \$ a day<sup>6)</sup>.

European experience<sup>7)</sup> indicates that patients whose surgical wounds healed without sepsis left the hospital on an average 1.8 days earlier than the time initially expected, whereas patients with sepsis had to stay an average of 7.3 days longer than was foreseen. In North Carolina it was found<sup>8)</sup> that surgery patients with hospital acquired infections stayed nearly twice as long as surgical patients without postoperative infections — on the average between 8.65 and 21.75 days longer.

During 42 weeks there were 144 patients treated in the Surgical Professorial Unit at the Royal Prince Alfred Hospital, Sydney, Australia, whose clean wounds became infected<sup>9)</sup>. The number of extra days spent in the hospital by these 144 patients total 1,939 days. This bed space is equivalent to the entire 30 bed unit being closed for 9 weeks.

The average duration of hospitalization for a patient on the neurosurgical service, who developed infections has been given more than one month longer than that required for the uncomplicated case<sup>10)</sup>.

Obviously, one of the components of the surgical act — the observance of the aseptic technique — must be considered specially. The aseptic technique consists of minimizing or if possible eliminating all sources and ways of contamination of the wound. It could be said that this technique is actually a mode of behavior or as Williams, Blowers, Garrod and Shooter have phrased: the observance of a set of rules designed to isolate small susceptible areas on patients from the ambient infective environment.

Some of these rules are based on adequate evidence, some can be recommended provisionally, but need further evaluation, some are rational routines, which are considered to be desirable but cannot be evaluated and some are traditionally observed practices, which are probably unnecessary or sometimes potentially harmful.

Staff changing to theatre garments and shoes, aseptic washing of hands; masking, gowning and assumption of cap, apron and gloves is all part of present-day aseptic technique. The majority of these modes and procedures as a part of the current aseptic technique complicates the general ease in the management of operations, and could thus be regarded as *dysfunctional*.

---

6) Personal communication: Jan Kjellander MD, Örebro.

7) Incidence of surgical wound infection in England and Wales. 1960, The Lancet 2:663.  
Ljungqvist U: Wound sepsis after clean operations. 1964, The Lancet 1:1095—1097.

8) Sperry Howard E and Craddock John: It pays to spend money for infection control. 1968, Modern Hospital 111:3:128.

9) May James, Chalmers J P, Loewenthal John, Rountree Phyllis M: Factors in the patient contributing to surgical sepsis. 1966, Surgery, Gynecology & Obstetrics 122:1:28—32.

10) Balch Richard E: Wound Infections Complicating Neurosurgical Procedures. 1967, Journal of Neurosurgery 26:1:44.

In the planning and designing procedure both the functions and dysfunctions are to be regarded as equal factors. The functions are in the surgical unit more constant, the dysfunctions have a tendency to change.

The patient's state of mind has bearing on the success of the operation and postoperative period. There are indications that preoperative confidence based on a good patient—surgeon relationship and a reality image of surgery can simplify postoperative surgical convalescence <sup>11)</sup>.

The patient facing surgery has often fear of pain, is apprehensive of the outcome, and is insecure in the strangeness of the hospital.

It has been found that the single most important cause of preoperative anxiety in the otherwise wellbalanced patient is a fear of the unknown, including the fear of the possibility of permanent incapacity.

The relative period of relaxation is terminated by the entrance of the anaesthesiologist. This produces a marked increase in heart rate, greater even than during insertion of the intravenous needle <sup>12)</sup>.

In 20 per cent of cases children's fears of surgery resulted in severe postoperative reactions <sup>13)</sup>. The overall incidence of anxiety in the series of Norris and Baird <sup>14)</sup> was 60 per cent, being more common in the female patients than in the male.

Negative emotions during the preoperative period may cause pathologic changes in the function of several organs <sup>15)</sup>. Malignant anxiety may even lead to death on the operating table <sup>16)</sup>. Thus anxiety and fear may be considered to increase the hazards of anaesthesia and surgery.

The immediate hours and minutes before operation may be a time of extreme apprehension for the patient. Therefore the patient should approach the surgical procedure in confidence, calmly and with expectation of success.

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- 11) Kolouch Fred T: Indications for Psychiatric Evaluation of the Surgical Patient. 1968, *The Journal-Lancet* 88:87—90.
  - 12) Williams James G L and Jones John R: Psychophysiological Responses to Anaesthesia and Operation. 1968, *JAMA, The Journal of American Medical Association* 203:6:415—417.
  - 13) Hughes Robert B: Children's fears of surgery. 1967, *Hospital Topics* 45:9:116—117.
  - 14) Norris Walter and Baird W L M: Pre-operative anxiety: a study of the incidence and aetiology. 1967, *British Journal of Anaesthesia* 39:503—509.
  - 15) cf also Raaga H: Kirurgilisest operatsioonist tingitud naha elektritakistuse muutused. Tartu Riikliku Ülikooli Toimetused. Arstiteaduslikke töid XII. Tartu 1965, p. 286.
  - 16) Marmer Milton J: Hypnosis a valuable aid in allaying fears of surgery. 1968, *Hospital Topics* 46:8:65.



The patient of today is probably more conscious of his surroundings than was his counterpart in the past. The patient with aesthetic sensibilities will be acutely distressed by unpleasant sounds, sights and odours, and intolerant of disarray <sup>17)</sup>.

The role which pleasant environment plays in influencing the state of mind of a patient facing surgery is especially distinct, not least in case of child patients.

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<sup>17)</sup> cf also Brunner Lilian Sholtis, Emerson Jr Charles Philips, Ferguson L Kraeer and Suddarth Doris Smith: Textbook of medical-surgical nursing. J B Lippincott Company. Philadelphia and Toronto 1964, p. 7.

Although the healing of a wound occupies a prime position in the priority schedule for body functions, there is a great gap in knowledge and of understanding in precise terms, the numerous factors governing the tissue defences and other biochemical processes in wound healing.

Wound infection remains a mystery as to its causative factors<sup>1)</sup>.

As also Morris, Barnes and Burke<sup>2)</sup> state, there has been despite substantial efforts no improvement in the incidence of sepsis after clean postoperative incisions over the past twenty years. There is no satisfactory explanation as to why 2 to 6 per cent of healthy patients develop postoperative incisional sepsis following what is called clean surgical procedures, while the remaining patients heal despite essentially similar operative procedures and under similar circumstances.

In the majority of cases the normal body defences dispose of organisms inoculated during operation. Body defences in a healthy host are said to kill 50 to 99.9 per cent of bacteria originally constituting a primary lodgement<sup>3)</sup>.

The number of bacteria needed to create a suppurative lesion varies according to the physiological state of the tissue in which the bacteria find themselves. A clean undrained closed wound does not become infected unless there is a greater number of staphylococci. Surveys indicate significantly that the presence of the bacteria in the wound at the end of an operation does not necessarily presage the subsequent development of infection or sepsis<sup>4)</sup>.

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1) cf also Krizek Thomas J and Davis John H: Endogenous wound infection. 1966, The Journal of Trauma 6:239.

2) Morris P J, Barnes B A and Burke J F: The Nature of the »Irreducible Minimum« Rate of Incisional Sepsis. 1966, Archives of Surgery 92:367—370.

3) cf also Howe Chester W: Experimental studies on determinants of wound infection. 1966, Surgery, Gynecology & Obstetrics 123:507—514.

4) cf also Cutler Elliot C, Morton Paul C and Sandusky William R: Observations on the prophylactic use of penicillin in the wounds of aerial warfare. 1944, The British Journal of Surgery 32:210—211.

Culbertson W R, Altemeier W A and Gonzales L L: Studies on the epidemiology of postoperative infection of clean operative wounds. 1961, Annals of Surgery 1954:599.

Postoperative wound infections. Report of an ad hoc Committee of the Committee on Trauma, Division of Medical Sciences, National Academy of Sciences, National Research Council. 1964, Annals of Surgery 160:2. Suppl. to 2:125.

Howe Chester W: Bacterial Flora of Clean Wounds and Its Relation to Subsequent Sepsis. 1964, The American Journal of Surgery 107:696—700.

Irmer W: Verhütung der Wundinfektion. in Intra- und postoperative Zwischenfälle. ed by Georg Brandt, Hubert Kunz and Rudolf Nissen. Vol. I, Georg Thieme Verlag. Stuttgart 1967, p. 157.

Beal Charles B, Epinosa Hernan, Sites Daniel P, Watson Milton J and Cox Dale: A surgical wound isolator. 1967, The Lancet 1:57—101.

The sources of contamination which lead to the development of a post-operative infection may be endogenous or exogenous. Infection which gains entrance into the wound from the patient's own organism — the medium — is called endogenous, the infection penetrating into the tissues from the external environment — the inoculum — exogenous.

## Pathogenic micro-organisms

The principal types of micro-organisms capable of harming the surgical patient are staphylococci (*aureus*), *Pseudomonas aeruginosa*, streptococci, the enteric bacilli and the clostridia.

Of these the staphylococci have received most attention as these micro-organisms have represented the commonest cause of localized suppurative infections. Although most strains of *Staphylococcus aureus* produce a number of biologically active toxins and enzymes, the mechanisms underlying the development and persistence of disease are poorly understood<sup>5)</sup>. The absence of fundamental knowledge about the pathogenesis of staphylococcal disease have resulted in a serious limitation of the methods available for its prevention<sup>6)</sup>.

Haemolytic streptococcus (*Streptococcus pyogenes*) is no longer considered a serious hospital menace. Streptococcal infections are not common and when they occur can be usually treated. Some data indicate that streptococcal diseases may represent a greater health hazard in subtropical and tropical regions than is appreciated at present<sup>7)</sup>.

Clostridial infections, incomparably less frequent, are reported mostly as the result of particles contaminated with pathogenic spores having come in contact with the wound.

Hospital acquired infections due to viruses are recognized, although they have received little attention. Their mode of transmission and role in postoperative wound infection has not yet been demonstrated.

A change in the nature of the infection problem has recently been reported with a relative decline in the importance of staphylococcus organisms and a rise in the number of infections caused by Gram-negative bacilli, which seem to have become a threat in contemporary surgical practice.

Infections caused by *Pseudomonas aeruginosa* (*Ps. pyocyanea*) have become more frequent and have proved troublesome. New studies in microbiology

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5) cf also Morse Stephen: Staphylococci and other Micrococci, in Bacterial and Mycotic Infections of Man, ed by Rene J Dubos and James G Hirsch. Pitman Medical. London 1965, p. 412.

6) Streptococcal and Staphylococcal Infections. Report of a WHO Expert Committee. World Health Organization Technical Report Series No 394. Geneva 1968, p. 53.

7) *ibid*, p. 6.



demonstrate that any micro-organism can be a pathogen. Infections are being traced today to organisms once considered benign. The *Serratia marcescens*, for instance, an organism used in experiments to track the spread of organisms, emerges as a serious contaminant of transplant patients.

In the following sections of this study attention is paid mainly to the staphylococci.

## The patient himself as a cause of infection

Until recent times the patient himself has been little appreciated as a factor contributing significantly to postoperative infection. Self-infection of surgical wounds with *Staphylococcus aureus* from carrier sites in the patient's own body has been believed to be a much less frequent cause of sepsis than is cross-infection from external sources<sup>8)</sup>.

Now there is a growing number of researchers<sup>9)</sup> who are becoming convinced that it is the susceptible host or tissue structure and physiology which is the weak link in the chain, and that the endogenous sources are decisive for the development of postoperative infections.

According to Williams, Jevons, Shooter, Hunter, Girling, Griffith and Taylor<sup>10)</sup> a relation exists between staphylococcal carriage and an increased risk of sepsis. These views have been supported by Lindbom and Laurell<sup>11)</sup> and others.

Cohen, Fekety jr and Cluff<sup>12)</sup> emphasize the increased risk of wound infection in patients with a remote infection unrelated to their operative wounds. The studies by Krizek and Davis<sup>13)</sup> demonstrate that a clean surgical wound readily becomes contaminated by staphylococci when present as an infection elsewhere in the body.

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8) cf also Bassett H F M, Ferguson W G, Hoffman E, Walton M, Blowers Robert and Conn Connie Anderson: Sources of Staphylococcal Infection in Surgical Wound Sepsis. 1963, The Journal of Hygiene 61:83—94.

9) cf also Cruickshank R: Definition of the problem: Synthesis. in Infection in Hospitals. ed by R E O Williams and R A Shooter, Blackwell. Oxford 1963, p. 49.

Michaelsen G S, Vesley D and Halbert M M: Laminar flow studied as an aid in care of low-resistance patients. 1967, Hospitals 41:12:105.

Altmeier William A, Culbertson William R and Hummel Robert P: Surgical Considerations of Endogenous Infections — Sources, Types and Methods of Control. 1968, Surgical Clinics of North America 48:1:227—240.

10) Williams R E O, Jevons M P, Shooter R A, Hunter C J W, Girling J A, Griffith J D, Taylor G W: Nasal staphylococci and sepsis in hospital patients. 1959, British Medical Journal 2:658—662.

11) Lindbom Gunnar and Laurell Gunnar: Studies on the Epidemiology of Staphylococcal Infections. 4. Effect of Nasal Chemotherapy on Carrier State in Patient and on Postoperative Sepsis. 1967, Acta Pathologica et Microbiologica Scandinavica 69:237—245.

12) Cohen L S, Fekety jr C R and Cluff L E: Studies of the epidemiology of staphylococcal infection. VI. Infections in the surgical patients. 1964, Annals of Surgery 159:321—334.

13) Krizek T J and Davis J H: Endogenous Wound Infection. 1966, Journal of Trauma 6:239.

The endogenous sources of contamination may not only be from the patient's blood and lymph vessels, upper or lower respiratory tract, his gastro-intestinal tract and his genito-urinary tract, but even from his body surfaces, particularly the following areas: under the jawl, the groin and the armpits.

Cole and Bernard<sup>14)</sup> have found that usually skin preparation is inadequate in order to eliminate the pathogenic organisms from the deeper recesses of the skin and to prevent massive contamination of the wound following wetting of the skin with blood or saline. Cole<sup>14A)</sup> has later emphasized the conviction that wound infections do arise largely from contamination from the patient himself.

This all indicates that considerable thought must be given to the patient as a source of his own infection. Probably first the use of surgical isolator technique and body isolators during the preoperative and postoperative periods offers a full explication to the roles of exogenous and endogenous bacteria in postsurgical infections.

The *age of the patient* has been found to exert a direct influence on wound sepsis rate, which rises steadily from the (10)15 to 24-year old group to the 65 to 74-year old group<sup>15)</sup>, it generally being stated that as age increases complications and multiple diagnoses become more frequent.

Contrary to these findings Lindbom, Laurell and Grenvik<sup>16)</sup> have stated that if age is a determinant, its importance is lost among the effects of many other factors which contribute to the septic outcome, also Sonneland<sup>17)</sup> found that age was not associated with an increased rate of sepsis.

The *sex of the patient* is not, by itself, related to risk of sepsis<sup>18)</sup>.

The incidence of infection has been shown to rise with *obesity, steroid administration and gross malnutrition*<sup>18)</sup>.

---

14) Cole William R and Bernard Harvey R: Relationship of skin carriage to postoperative staphylococcal wound infection. 1964, Surgical Forum 15:52–54.

14A) Cole William R in 1968, Archives of Surgery 97:369.

15) Postoperative wound infections. Report of an ad hoc Committee of the Committee on Trauma. Division of Medical Sciences. National Academy of Sciences. National Research Council. 1964, Annals of Surgery. 160:2. Supplement to 2, p. 125.

Hegeman G: Wundheilung und Wundbehandlung. in H Hellner, R Nissen and K Vosschulte: Lehrbuch der Chirurgie. Georg Thieme Verlag. Stuttgart 1967, p. 10.

16) Lindbom Gunnar, Laurell Gunnar and Grenvik Åke: Studies on the Epidemiology of Staphylococcal Infections. 3. Influence of Factors Inherent in the Patient and his Operation. 1967, Acta Pathologica et Microbiologica Scandinavica 69:219–236.

17) Sonneland John: Postoperative infection: II. Etiological Factors. 1966, Pacific Medicine and Surgery 74:165–169.

18) Postoperative wound infections. Report of an ad hoc Committee of the Committee on Trauma. Division of Medical Sciences. National Academy of Sciences. National Research Council. 1964, Annals of Surgery. 160:2, Supplement to 2, p. 125.

Later Andersson, Borgström and van der Linden<sup>19)</sup> have found that obese patients are not more liable to infection of the wound than non-obese.

Lindbom, Laurell and Grenvik<sup>20)</sup> have found that the incidence of post-operative sepsis in connection with thoracic surgery showed a positive correlation to numerous non-bacterial factors, such as underlying disease, functional state of heart and lungs and type of surgical procedure.

The study by Conolly and Golovsky<sup>21)</sup> of potentially avoidable infections gave as the most important predisposing factors *anaemia* and *wound haematoma*.

Sonneland<sup>22)</sup> has associated *postoperative inactivity* with a higher rate of sepsis.

The probability of postoperative infection is reduced by having the patient in optimal condition at the time of the operation.

## Staff as a cause of infection

Contamination for various personnel activities ranges anywhere from 100,000 to 30,000,000 particles of 0.3  $\mu$  and larger in size per minute<sup>23)</sup>. A person sitting and moving lightly head, hand and forearm emits 500,000 particles and sitting with average body and arm movements increases the production to 1,000,000. Changing positions from sitting to standing gives off 2,500,000 particles per minute.

Probably nothing releases more bacteria than the common act of dressing and undressing. Of all areas studied by Bond, Halbert, Putnam, Rushmeyer and Vesley<sup>24)</sup> doctors' dressing rooms were generally the most heavily contaminated.

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19) Andersson Å, Borgström S and van der Linden W: The Incidence of Infection in Clean Surgical Wounds. 1967, Acta Chirurgica Scandinavica 133:13–16.

20) Lindbom Gunnar, Laurell Gunnar and Grenvik Åke: Studies on the epidemiology of Staphylococcal infections. 3. Influence of Factors Inherent in the Patient and his Operation. 1967, Acta Pathologica et Microbiologica Scandinavica 69:219–236.

21) Conolly W Bruce and Golovsky David: Postoperative Wound Sepsis. 1967, The Medical Journal of Australia 1:643–645.

22) Sonneland John: Postoperative infection. II. Etiological Factors. 1966, Pacific Medicine and Surgery 74:165–169.

23) Austin Philip R and Timmerman Stewart W: Design and operation of clean rooms. Business News Publishing Company. Detroit, Michigan 1965, p. 77.

24) Bond R G, Halbert Mary M, Putnam Hugh D, Rushmeyer Orlando R and Vesley Donald: Survey of microbial contamination in the surgical suites of 23 hospitals. University Health Service and School of Public Health. University of Minnesota. Minneapolis. Minn. Stencil. March 1964, p. 57.

A rapid increase in the bacterial count has been recorded even, when personnel gowned, capped, masked and wearing rubber boots enter the theatre and go through a normal operative routine<sup>25)</sup>.

Studies under working conditions<sup>26)</sup> indicate that the area of maximum deposition usually occurs around the anaesthetist and the head of the patient.

The staff<sup>27)</sup>, particularly the nonscrubbed personnel<sup>28)</sup>, are to be considered the most important exogenous source of contamination.

Shooter<sup>29)</sup> has declared that even if hand carriers are a danger in the theatre from time to time, almost any part of the body may be a genuine site of skin carriage.

Extensive research and careful attention have been paid to the documented role of *body surfaces* and *hair* as a source of contamination<sup>30)</sup>.

The work of Noble and Davies<sup>31)</sup> suggests that it is the total load of staphylococci on the skin, rather than carriage in one particular dispersal site that is

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25) cf also Shaffer James G and McDade Joseph M: The microbial profile of a new hospital. 1964, *Hospitals* 38:5:40–51.

26) leRiche W Harding, Balcom Carolee E and van Belle Gerald: The Control of Infections in Hospitals. University of Toronto Press. Toronto 1966, p. 77.

27) Hart Deryl: Operation Room Infections. 1937, *Archives of Surgery* 34:874.

Bröckner J and Jessen C: Risks of Airborne Infection at Operation. 1963, *Acta Chirurgica Scandinavica* 125:8–13.

Shaffer James G, Migit David and Key Iris: The microbiological profile of two hospitals of differing structures. 1965, *Hospitals* 39:18:176.

Krynski S and Debicki K: Dzienne watrania w skladzie jakosciowym i ilosciowym zarazkow w powietrzu izby operacyjnej. 1966, *Polski Przegląd Chirurgiczny* 38:94–99.

Payne Richard W: Severe Outbreak of Surgical Sepsis Due to *Staphylococcus aureus* of Unusual Type and Origin. 1967, *British Medical Journal* 4:17–20.

Illingworth Sir Charles and Dick Bruce M: A textbook of surgical pathology. J & A Churchill Ltd. London 1968, p. 39.

28) Burke John F: Wound infection and early inflammation. 1964, *Monographs in the Surgical Sciences* 1:4:317.

29) Shooter R A: Staphylococcal infections: Synthesis. in *Infection in Hospitals*. ed by R E O Williams and R A Shooter. Blackwell. Oxford 1963, p. 102.

30) cf also Bernard Harvey R: Study Shows Most OR Contamination Traced to People Came from Skin. 1964, *Hospital Topics* 42:6:98.

Summers M M, Lunch P F and Black T: Hair as a reservoir of staphylococci. 1965, *Journal of Clinical Pathology* 18:13–15.

Noble W C: *Staphylococcus aureus* on the air. 1966, *Journal of Clinical Pathology* 19:570–572.

Hearst Bella R and Blumenthal Harold J: High Incidence of *Staphylococcus aureus* in Human Hair. American Society for Microbiology. Bacteriological Proceedings 1967. Abstracts of the 67<sup>th</sup> Annual Meeting. New York, 30 April – 4 May 1967, p. 62.

31) after Williams R E O: Pathogene on the Skin. in *Skin Bacteria and Their Role in Infection*. ed by H I Maibach and G Hildick-Smith. McGraw-Hill Book Company. New York, Sydney, Toronto, London 1965, p. 57.



important. From studies upon the aerial concentration of bacterial particles emanating from personnel, it appears that the emission is more often constant than intermittent. The level of concentration usually rises or falls slowly and only occasionally increases sharply<sup>32)</sup>.

It has been stated that the bacterial dispersion is always more liberal from below the waist than from above it and that perineum is a particularly important source of staphylococcal aerosol<sup>33, 34)</sup>. Although Blowers and McCluskey<sup>35)</sup> state that dispersal of *Staphylococcus aureus* by female attire has not yet been demonstrated, Ulrich's<sup>36)</sup> findings indicate that no sex-linked differences are apparent except possibly the higher population on the groin of males. Also Solberg<sup>33)</sup> found no sex-linked differences.

The *respiratory tract*, particularly the nasopharynxes of the staff is another well documented<sup>37)</sup> source of pathogenic organisms connected with postoperative wound infections. Bacteria arising from the naso-pharynx, however, constitute only a small fraction of the total shed into the environment.

Most of the many hospitals staff *Staphylococcus aureus* carriers release the organisms in insignificant numbers; but a few release and disseminate staphylococci in vast clouds<sup>38)</sup>. An active carrier-disperser may disseminate more than ten times as much as the average carrier<sup>39)</sup>.

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32) Kethly T: The Factors in Ventilation of Airborne Particles. Paper read at the Communicable Disease Center. Atlanta. September Course 1963.

33) Solberg Claus Ola: A Study of Carriers of *Staphylococcus Aureus*. Acta Medica Scandinavica. Supplementum 436. Bergen 1965, p. 79.

34) Bethune D W, Blowers Robert, Parker Michael and Pask E A: Dispersal of *Staphylococcus aureus* by patients and surgical staff. 1965, The Lancet 1:480—483.

35) Blowers Robert and McCluskey Maureen: Design of operating room dress for surgeons. 1965, The Lancet 2:681—683.

36) Ulrich John A: Dynamics of Bacterial Skin Populations. in Skin Bacteria and Their Role in Infection. ed by H I Maibach and G Hildick-Smith. McGraw-Hill Book Company. New York, Sydney, Toronto, London 1965, p. 234.

37) cf also Walter Carl W, Kundsinn Ruth B and Brubaker Mary M: The Incidence of Airborne Wound Infection During Operation. 1963, JAMA. The Journal of the American Medical Association 196:908—913.

Huysmans-Evers A G M and van der Kolk M M: De epidemiologie van *Staphylococcus aureus* in de chirurgische Kliniek. 1966, Nederlands Tijdschrift voor Geneeskunde 110:1381—1387.

Regamey R H and Garcia J M: Problèmes posés par l'hospitalisme dans un service de chirurgie. 1966, Pathologia et Microbiologia 29:553—557.

Ford Clynn R, Peterson Daryl E and Mitchell Charles R: An Appraisal of the Role of Surgical Face Mask. 1967, The American Journal of Surgery 113:788.

38) Hare R and Thomas C G A: Transmission of *Staphylococcus aureus*. 1956, British Medical Journal 2:840.

39) Lidwell O M, Richards I D G and Polakoff S: Comparison of three ventilating systems in an operating room. 1967, Journal of Hygiene 65:202.

Traffic and dress control as well as work density in the operating theatre have been shown to have relatively strong correlation with microbial surface contamination<sup>40)</sup>.

Shaffer and McDade<sup>41)</sup> state that although increased activity usually generates an increase in the bacterial count, there are fairly frequent exceptions. It is not unusual to find normal counts in areas where much activity has been recorded.

Gillquist<sup>42)</sup> states that the increase of people present during the operation gives an increase in the incidence of wound infection. This might be explained by the fact that more complicated operations often require the presence of a larger operating team. Velghe, Doreymarker and van de Voorde<sup>43)</sup> found no correlation with the number of people in the operating room in connection with neurosurgery.

Although correlations have not been established, strict traffic control in the operating theatre appears to be a rational recommendation.

A striking finding of a major study<sup>44)</sup> has been the great difference in infection rates for given operative procedures between one hospital taking part in the investigation and another. This would appear to place a considerable responsibility upon the skill of the operating team for the development of many postoperative wound infections<sup>45)</sup>.

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40) Bond R G, Halbert Mary M, Putnam Hugh D, Rushmeyer Orlando R and Vesley Donald: Survey of microbial contamination in the surgical suites of 23 hospitals. University Health Service and School of Public Health. University of Minnesota. Minneapolis, Minn. Stencil March 1964, p. 58.

Lidwell O M, Richards I D G and Polakoff S: Comparison of three ventilating systems in an operating room. 1967, *Journal of Hygiene* 65:199.

41) Shaffer James G and McDade Joseph M: The microbial profile of a new hospital. 1964, *Hospitals* 38:5:40–51.

42) Gillquist Jan: Sårinfektioner på en gammal och en ny operationsavdelning. 1967, *Läkartidningen* 64:1220.

43) Velghe L, Doreymarker A and van de Voorde H: Récouvillon du champ opératoire en neurochirurgie. Analyse d'un milieu de contrôles. 1964, *Acta neurochirurgica* 11:686–693.

44) Postoperative Wound Infections. Report of an ad hoc Committee of the Committee on Trauma. 1964, *Annals of Surgery* 160:2. Supplement to 2.

45) cf also Dykes E R and Anderson R: Atraumatic Technic: the Sine Qua Non of Operative Wound Infection Prophylaxis. 1961, *Cleveland Clinical Quarterly* 28:157.

Wilde J, Schwanke M: Häufigkeiten und Ursachen postoperativer Wundheilungsstörungen. 1967, *Zentralblatt für Chirurgie* 92:1091–1092.

Irmer W: Verhütung der Wundinfektion. in *Intra- und postoperative Zwischenfälle*. ed by Georg Brandt, Hubert Kunz and Rudolf Nissen. vol. I. Georg Thieme Verlag. Stuttgart 1967, p. 154.

Altmeier William A: Type of surgery, technic of surgeon among factors in postoperative infection. 1967, *Hospital Topics* 45:12:83.

Buckwalter Joseph A and Smith Ian M: Surgical infections. in *Synopsis of surgery*. ed by Richard D Liechty and Robert T Soper. The C V Mosby Company. Saint Louis 1968, p. 95.



Silvola, Tala and Orko<sup>46)</sup> have stated that a high standard of caution in surgical technique may be of even greater significance than initial bacterial contamination.

In many sectors of surgery a refined technique diminishes the risk of sepsis, for the tissue handling is improved and the amount of blood filling the wound reduced. It has been agreed that the appreciation of gentleness in handling tissues and the use of careful techniques are mandatory to lessen infections.

Wound fluid is bacteriostatic and bacteriocidal, but the least amount of traumatized tissue greatly reduces the resistance to the wound infection<sup>47)</sup>.

In a wound where there has been extensive tissue damage, changes of the arterial blood supply or the presence of a foreign body such as a drain or metal implant or other foreign material, only small numbers of pathogenic micro-organisms are necessary for the development of postoperative infection<sup>48 49)</sup>. The presence of a single suture enhances the invasiveness of staphylococci by a factor of 10,000<sup>48)</sup>.

Attention has been drawn to extensive damage made by percutaneous sutures<sup>50)</sup> and suture needles in their transepidermal and transdermal penetration. The reactions of the needles have been shown to be far more severe, extensive, and prolonged than those to the scalpel incision itself<sup>51)</sup>.

How far this kind of damage influences the occurrence of wound infection is not known.

In the studies of Mendoza, Watne, Grace and Moore<sup>52)</sup> cancer patients with wire closures had a significantly higher incidence of wound infection than did those with silk closures.

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46) Silvola H, Tala P and Orko R: Skin bacteriology and surgical wound infection. 1967, Scandinavian Journal of Thoracic and Cardiovascular Surgery 1:61—63.

47) cf also Dunphy J Englebert: The Healing of Wounds. 1967, The Canadian Journal of Surgery 10:281—287.

48) Elek S D and Conen P E: The Virulence of Staphylococcus Pyogenes for Man. A study of wound infection. 1957, Journal of Experimental Pathology 38:573—586.

49) Barron J N: Theatre drill and wound sepsis. in Operating Theatres and Ancillary rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 48—58.  
Towers A G: Wound infection in an orthopaedic hospital. 1965, The Lancet 2:379—381.

50) cf also Carpendale M T F and Sereda W: The role of the percutaneous suture in surgical wound infection. 1965, Surgery 58:672—677.

51) Ordman L J and Gillman T: Studies in the healing of cutaneous wounds. 1966, Archives of Surgery 93:857—928.  
Hegemann G: Wundheilung und Wundbehandlung. in H Hellner, R Nissen and K Vosschulte: Lehrbuch der Chirurgie. Georg Thieme Verlag. Stuttgart 1967, p. 9.

52) Mendoza Catalino B, Watne Alvin L, Grace James E and Moore George E: Wire versus Silk: Choice of Surgical Wound Closure in Patients with Cancer. 1966, The American Journal of Surgery 112:839—845.

Wound sepsis rates have generally been believed to rise as the *duration of the operation* increases<sup>53)</sup>. Burke<sup>54)</sup> found the increase to be directly proportional to the increase in operating time only for the first two or three hours and Edmunds, Drummond, Chalmers, Gillie et al<sup>55)</sup> that wound sepsis was more frequent in operations lasting over an hour than in those taking less.

May, Chalmers, Loewenthal and Rountree<sup>56)</sup> have shown that there is correlation between the duration of operation and the subsequent septicemia in patients undergoing a procedure lasting at least two hours.

Velghe, Doreymarker and van de Voorde<sup>57)</sup> found in connection with neurosurgery and Goodman, Schaffer, Collins, Battersby and Koenig<sup>58)</sup> in connection with cardiovascular surgery a relationship between wound sepsis rate and the length of the procedure.

On the other hand a simple analysis by Lindbom, Laurell and Grenvik<sup>59)</sup> of comparable operations, infected and noninfected, failed to reveal a direct time-risk relation. Even Gillquist<sup>60)</sup> found that there is no significant rise in the risk of wound infection in connection with increased operating time.

It might be concluded that the duration of operation does not exert any substantial influence on sepsis rates.

This is also the case with the *urgency of operation*, *time of day* when the operation is performed, *season*, and *month* according to an American survey<sup>61)</sup>.

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- 53) Lindbom Gunnar: Studies of the Epidemiology of Staphylococcal Infections. 1964, Acta Chirurgica Scandinavica 128:430.  
Postoperative wound infections. Report of an ad hoc Committee. National Research Council. 1964, Annals of Surgery. 160. Supplement to 2:125.
- 54) Burke John F: Wound Infection and Early Inflammation. 1964, Monographs in the Surgical Sciences, 1:4:313.
- 55) Edmunds P N, Drummond W, Chalmers T S, Gillie T A, Whitelaw R G, Train T S R, Paterson W I and Spence A J: Sepsis in three Scottish non-teaching Hospitals. 1965, Scottish Medical Journal 10:209–214.
- 56) May James, Chalmers J P, Loewenthal John, Rountree Phyllis M: Factors in the patient contributing to surgical sepsis. 1966, Surgery, Gynecology & Obstetrics 122:1:31.
- 57) Velghe L, Doreymarker A and van de Voorde H: Récouillon du champ opératoire en neurochirurgie. Analyse d'un milieu de controles. 1964, Acta neurochirurgica 11:686–693.
- 58) Goodman Jay S, Schaffer William, Collins Harold A, Battersby Edward J and Koenig M Glenn: Infection after cardiovascular surgery. 1968, The New England Journal of Medicine 278:117–123.
- 59) Lindbom Gunnar, Laurell Gunnar and Grenvik Åke: Studies on the epidemiology of Staphylococcal infections. 3. Influence of Factors Inherent in the Patient and his Operation. 1967, Acta Pathologica et Microbiologica Scandinavica 69:219–236.
- 60) Gillquist Jan: Sårinfektioner på en gammal och en ny operationsavdelning. 1967, Läkartidningen 64:1224.
- 61) Postoperative Wound Infections. Report of an ad hoc Committee of the Committee on Trauma. Division of Medical Sciences. National Academy of Sciences. National Research Council. 1964, Annals of Surgery. 160, 2. Supplement to 2, p. 125.

Sonneland<sup>62)</sup> found no relationship between infection and *operating list order*, at least for inpatients undergoing surgery of the stomach and colon.

However, the view on the unimportance of urgency is contradicted by Sonneland<sup>63)</sup> who found that data point toward increasing mortality and sepsis among those subjected to rapid surgery. According to Kippax and Thomas<sup>64)</sup> emergency cases carry a significantly higher sepsis rate than the elective ones.

The view on unimportance of the time of day is contradicted by Stewart and Douglas<sup>65)</sup>, who state that there is a significant association between a high rate of sepsis in operation and a late position on the list, and that this effect is independent of the duration of the operation, the size of the incision, drainage, age of patient etc. The cause of the association Stewart and Douglas felt might be an undetected artefact in the data, fatigue and carelessness on the part of staff who want to get home to dinner, on the one hand or operating theatre contamination on the other.

Other research has shown that in certain tests some people do better in the morning, some in the evening, and the difference is correlated with two types of personality — the introverts, scoring higher in the mornings and extraverts, scoring in the evening.

Ljungquist's<sup>66)</sup> findings seems to confirm the opinion of Stewart and Douglas. Surgical operations performed in the afternoon he found were more susceptible to infection than those performed in the morning. Lundquist<sup>67)</sup> showed that the time from 14<sup>00</sup> to 16<sup>00</sup> hours was most dangerous for operating from the point of view of infection, assuming an early morning start. He suggested that a theatre after six hours' work should be rested. Even Gillquist<sup>68)</sup> has found an increase of incidence of wound infections in connection with operations carried out in the afternoons.

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62) Sonneland John: Postoperative Infection. II. Etiological Factors. 1966, Pacific Medicine and Surgery 74:166.

63) Sonneland John: Postoperative Infection. III. Surgeons, Speed and Sepsis, 1966, Pacific Medicine and Surgery 74:233.

64) Kippax P W and Thomas E T: Surgical wound sepsis in a general hospital. 1966, The Lancet 2:1299.

65) Stewart J S S and Douglas D M: Wound sepsis and operating list order. in Dix-neuvieme congrès de la Société Internationale de chirurgie. Dublin 2-9.9.61. Imprimerie Medicale et Scientifique. Brussels, no publishing year, p. 812—817.

66) Ljungqvist U: Wound sepsis after clean operations. 1964, The Lancet 1:1095—1097.

67) 1965, British Medical Journal 2:995.

68) Gillquist Jan: Sårinfektioner på en gammal och en ny operationsavdelning. 1967, Läkartidningen 64:1220.



So it has been<sup>69)</sup> concluded tentatively that operation load per theatre may be a very important factor in surgical wound sepsis, and it has been proposed<sup>70)</sup> that if possible not more than three major operations per day should be performed in one theatre. A working day of three major surgical operations would probably maintain good working conditions for one team.

## Time and place for arising post-operative infections

It has been mostly claimed that postoperative infections are initiated in the surgical theatre. Particularly the innumerable potential breaks in aseptic technique have been considered to constitute an exceedingly important predisposing cause of wound infection<sup>71)</sup>.

MacLeod<sup>72)</sup> gives as the average interval between operation and the appearance of exudate in wound 9.8 to 10.6 days. This long interval in itself casts doubt on the surgical theatre as the usual source of infection. As known from experimental infection of man and three laboratory animal species, the time required for typical abscess formation is rarely longer than 72 hours. Not surprisingly, in view of this shorter time it has been thought that the theatre is not so important as the ward in causing postoperative infection<sup>73)</sup>. Laurell and Lindbom<sup>74)</sup> have found that roughly two thirds of all investigated patients had acquired the infecting strains outside the operating theatre. Later they indicated<sup>75)</sup> that only about 22 per cent of postsurgical infections were not caused by endogenous factors or deficient conditions in the intensive care ward.

The risk of acquiring infections during the early postoperative phase through deficiencies in the open intensive care ward, particularly in connection with thoracic surgery, has been emphasized<sup>76)</sup>.

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69) Kippax P W and Thomas E T: Surgical wound sepsis in a general hospital. 1966, *The Lancet* 2:1297–1300.

70) Walker W F and Douglas D M: The surgeon's angle on the operating room. in *Operating Theatres and Ancillary Rooms*. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 150–151.

71) cf also LeMaitre George D and Finnegan Janet A: *The Patient in Surgery*. W B Saunders Co. Philadelphia and London 1965, p. 30.  
DeVito R V: Healing of wounds. 1965, *The Surgical Clinics of North America*, 45:453.  
Burke John F: Wounds and Infections. in *Surgery*. ed by George L Nardi and George D Zuidema. Little, Brown and Company. Boston 1965, p. 63–82.

72) MacLeod Colin: Hospital-acquired infections require hospital-inspired research. 1965, *Hospitals* 39:16:76–84.

73) cf also Rountree Phyllis M, Harrington Maureen, Loewenthal John and Gye Richard: Staphylococcal wound infection in a surgical unit. 1960, *The Lancet* 2:1–6.

74) Laurell Gunnar and Lindbom Gunnar: Wound infections due to *Staphylococcus pyogenes* in a thoracic surgical unit. 1961, *Acta Chirurgica Scandinavica* 121:165–175.

75) Lindbom Gunnar and Laurell Gunnar: Studies on the Epidemiology of Staphylococcal Infections. 5. Importance of Environmental Factors During the Early Postoperative Phase. 1967, *Acta Pathologica Scandinavica* 69:246–263.

76) Lindbom Gunnar: Studies of the Epidemiology of Staphylococcal Infections. 1964, *Acta Chirurgica Scandinavica* 128:430–433.

The duration of preoperative hospitalization seems to be another factor which appears to influence the infection rate independently<sup>77)</sup>. It follows that a prolonged preoperative stay in a regular ward — most likely a contaminated environment — is not advised. As a counter measure a preoperative ward has been suggested<sup>78)</sup> and should be accepted.

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- 77) cf also Postoperative wound infections. Report of an ad hoc Committee of the Committee on Trauma. Division of Medical Sciences. National Academy of Sciences. National Research Council. 1964, *Annals of Surgery* 160:2. Supplement to 2:125.
- Öberg Gösta: Infektionskliniker och sjukhusinfektioner. 1964, *Svenska Läkartidningen* 61:774–776.
- Irmer W: Verhütung der Wundinfektion. in *Intra- und postoperative Zwischenfälle*, ed by Georg Brandt, Hubert Kunz and Rudolf Nissen, vol. I. Georg Thieme Verlag. Stuttgart 1967, p. 157.
- 78) Hyde Jacobs Jr, Robert: Basic studies for the planning of surgical facilities. New York Chapter. The American Institute of Architects 1963.



Environment — the inoculum — has frequently been indicated as an important cause of infection.

All kinds of contaminated *instruments* and *equipment* which interfere with the actual area of operation may cause infection. This includes even shaving brushes used for depilation of scalps before neurosurgical operations <sup>1)</sup>.

The surgical instruments as sources of exogenous infection have become extremely rare because of developments in preoperative instrument handling.

There are more reports of pathogenic bacteria <sup>2)</sup> having been isolated from various parts of anaesthesia apparatus such as corrugated tubing, reservoir bags, Y-pieces, breathing bags, masks and from the metallic inhaling and exhaling tubes of a closed-circuit absorber.

Other workers <sup>3)</sup> state that it has not been demonstrated that any lessening in the incidence of respiratory tract infections takes place when sterile equipment is used. A carefully documented relationship between contaminated anaesthetic equipment and subsequent infection is needed.

Staphylococci disseminated into the *physical environment* may survive there for weeks. Their exact survival time depends on the heaviness of the original contamination and upon temperature and humidity. *Staphylococcus aureus* referable to a particular disseminator have been recovered from a room for ten days after he has vacated it. There are, however, few convincing reports in which a patient introduced into a contaminated room has acquired an organism derived from a patient who has previously vacated the room <sup>4)</sup>.

The physical environment of the operating room: the *walls*, *floors*, *ceilings* and *lights*, contributes only insignificant amounts of bacteria to the operating room air. Walls are of some importance only where they can be touched.

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1) Ayliffe G A et al: Hospital infection with *Pseudomonas aeruginosa* in neurosurgery. 1965, The Lancet 2:365-368.

2) eg Kundsinn R B and Walter C W: Asepsis for Inhalation Therapy. 1962, Anaesthesiology 23:507-512.

Show John C and Anderson Marion L: How Anaesthesiologist can lessen Infection. 1965, The Modern Hospital 165:4:128-133.

3) eg Cole W H J and Tucker J B F: Heat sterilization of the circle absorbtion unit: unit designed to withstand autoclaving. 1967, The Medical Journal of Australia 1:52-55.

Meeks Charles H, Pemberton Williams E and Hench Miles E: Sterilization of Anesthesia Apparatus. 1967, JAMA. The Journal of the American Medical Association 199:4:276-278.

4) Streptococcal and Staphylococcal Infections. Report of a WHO Expert Committee. World Health Organization. Technical Report Series No 394. Geneva 1968, p. 43.

Wypkema and Alder<sup>5)</sup> have demonstrated that the extent to which bacteria adhere to walls is very small. Froud, Alder and Gillespie<sup>6)</sup> have stated that walls yield few bacteria and ceilings and undersurfaces of lamps fewer still. Even the results of the Boyar, Brown Jr and Shaffer<sup>7)</sup> investigation stress that the ceiling is not a major source of sanitary concern. The investigators felt that attention should rather be focused on floors.

Growing uncertainty<sup>8)</sup> has been expressed about the role of floor bacteria as a source of hospital infection. Dust from floors seldom rises above knee-height as a result of the movement of people in a room.

It has been found quite naturally that horizontal surfaces in the operating room are more heavily contaminated by bacteria than the vertical. The heaviest growth of all was given by the swabs from the tops of the operating lamps<sup>6)</sup>. So it was felt that there is a certain risk, although unidentified, of infection by bacteria falling from the operating lamp, if the top, after cleaning is not smeared with oil such as liquid paraffin so that the bacteria which accumulate there are not readily dislodged. The problem obviously requires more study.

Particularly since Ives and Hirshfeld<sup>9)</sup> observed heavy seeding of clean wounds with staphylococci during operation, many investigators of the postoperative wound infection concentrated in the first place on *circulation of air*, believing that air is *the* transmission medium of organisms which cause surgical infections or at least giving it very much significance in the genesis of surgical infections<sup>10)</sup>.

The amount of airborne particles in an operating theatre can be very considerable. It could be estimated that a very quiet surgical team represents a

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5) Wypkema W and Alder V G: Hospital cross-infection and dirty walls. 1962, The Lancet 2:1066.

6) Froud P J, Alder V G and Gillespie W A: Contaminated areas in operating-theatre. 1966, The Lancet 2:961-963.

7) Boyar R E, Brown Jr W K and Shaffer H C: Radiant Ceilings Tested for Bacteria Count. 1966, The Modern Hospital 106:6:160-163.

8) cf also Ayliffe G A J, Collings B J and Lowbury E J L: Cleaning and Disinfection of Hospital Floors. 1966, British Medical Journal 2:44.

9) Ives Howard R and Hirshfeld John W: The bacterial flora of clean surgical wounds. 1938, Annals of Surgery 107:607-617.

10) cf also Duguid J P and Wallace A T: Airborne infection with dust liberated from clothing. 1948, The Lancet 2:845-849.

Shooter R A, Taylor G W, Ellis G and Ross, Sir James Paterson: Postoperative wound infection. 1956, Surgery, Gynecology & Obstetrics 103:257.

Blowers R and Crew B: Ventilation of operating theatres. 1960, Journal of Hygiene 58:427.

Lidwell O M and Williams R E O: The ventilation of operating theatres. 1960, Journal of Hygiene 58:449.

Gillespie W A: Hospital Infection, in Scientific Foundations of Surgery. ed by Charles Wells and James Kyle. William Heinemann Medical Books Ltd. London 1967, p. 608.

source of about 5,000 airborne particles per minute; the average surgical team a source of 10,000 particles per minute; and that many teams represent sources of 50,000 particles. These estimates represent at the same time three diffuse levels of house-keeping and personal practice: good (5,000), average (10,000) and poor (50,000) <sup>11)</sup>. In a regular operating theatre these values correspond to 36 particles/m<sup>3</sup> a minute in good practice, about 72 in average, and 360 in poor practice.

While sometimes a very great number of particles may be found — Beck <sup>12)</sup> has published a finding of 3,000,000 particles in the operative field in a regular operating theatre — bacteria have a very short life while airborne. It has been found <sup>13)</sup> that when organisms are atomized into air the rate of death is at first rapid and then slows down. There is a self-sterilizing effect remarkable within operating rooms if nothing is done to the air at all. This effect includes according to Cole, Bernard and Gravens <sup>14)</sup> much more than the simple settling out of the bacteria.

Droplet nuclei in themselves do not constitute the predominant mechanism of transmission of staphylococcus infections <sup>15)</sup>.

There seems to be a considerable divergence of opinion on what size of dust particle should be excluded from the operating theatre air supply: figures have varied between 1 - 50 m $\mu$ . The studies by Noble, Lidwell and Kingston <sup>16)</sup> show that organisms associated with human disease or carriage were usually found on particles in the range 4 to 20 m $\mu$  equivalent diameter.

Ma <sup>17)</sup> has limited the size of the particles having importance in that connection to between 10 to 16 m $\mu$ .

Concentration of airborne pathogenic organisms is very small. Although their presence is without question, it is unclear to what extent they contaminate and consequently infect clean surgical wounds, not at least because susceptibility to bacteria varies considerably in different individuals.

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11) Kethly T W: The Factors in Ventilation of Airborne Particles. Paper read at the Communicable Disease Center. Atlanta. September Course 1963.

12) Beck Wm C: Particulate contamination of the surgical wound. 1966, The Guthrie Clinic Bulletin 36:64-75.

13) Riley Richard L and O'Grady Francis: Airborne Infection. The MacMillan Company. New York 1961, p. 67.

14) Cole William R, Bernard Harvey R and Gravens Daniel L: Control of Airborne Bacteria in Operating Rooms. 1965, Hospitals 39:6:79-84.

15) cf also Riley Richard L and O'Grady Francis: Airborne Infection. The MacMillan Company. New York 1961, p. 166.

16) Noble W C, Lidwell O M and Kingston D: The size distribution of airborne particles carrying micro-organisms. 1963, The Journal of Hygiene 61:385-391.

17) Ma Wm Y L of the Hospital Engineering Research Unit, Glasgow, according to Reserapport från besök i Skottland och England, 25-30 januari 1965 av Anders Runefelt and David Södergren. Stencil. Stockholm 1965, p. 12.

Concerning the fall-out of *Staphylococcus aureus*, Duguid <sup>18)</sup> states that in a surgical theatre in which no special precautions are being taken against airborne infection, and in an operation lasting about an hour, one or two infected particles might fall into the wound and another 10, 20 or 30 might fall on to dressings, instruments and other materials likely to be introduced into the wound, most likely depending on the number of *Staphylococcus aureus* carriers in the theatre.

The studies by Davis <sup>19)</sup> would indicate that at best only one or two bacteria-carrying particles, which might contain pathogenic organisms, gain entrance to the wound through the air. These few bacteria-carrying particles gaining access to the wound might be of importance in a large wound such as a burn with a great deal of devitalized tissue or when in connection with transplantation surgery desensitized patients are involved. In most operative wounds, however, it is unlikely that the number of bacteria gaining entrance from the air, during the time of operation, play much of a role in the development of postoperative wound sepsis.

One of the other circumstances that casts distrust on the presumption of airborne infection is the rarity with which carriers in the surgical unit infect patients. E.g. the programs of Dineen and Himmelsbach et al <sup>20)</sup> on this subject have experienced a singular lack of success in finding the expected correlation between the carriers and the subsequent infections. It has been indicated that there are two kinds of *Staphylococcus aureus* hospital strains; one widely disseminated but less virulent, the other not so frequent, but causing purulent infections. Accordingly Williams <sup>21)</sup> has been able to state, that many dispersers shed what appear to be quite harmless staphylococci.

After studying postoperative wound infection in connection with 15,000 operations it was concluded <sup>22)</sup> that it is not primarily related to airborne bacteria. The risk of postoperative infection from airborne micro-organisms, introduced to the theatre through normal ventilation or otherwise, appeared to be unimportant as compared with other infection risks, unless the corridors of the surgical unit connect with the wards, which are quite close to the

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18) Duguid J P: Sources and Modes of Spread of Infection in Hospital. 1966, Journal of the Royal College of Surgeons of Edinburgh 11:268.

19) Davis John H: Staphylococcal Infection in Surgical Patients. 1967, The American Surgeon 33:642-649.

20) Hyde Jacobs Jr Robert: Basic Studies for the Planning of Surgical Service Facilities. New York Chapter. The American Institute of Architects. 1963, p. 2-3.

21) Williams R E O: Airborne staphylococci in the surgical ward. 1967, The Journal of Hygiene 65:207-217.

22) Postoperative wound infections. Report of an ad hoc Committee of the Committee on Trauma. National Research Council. 1964, Annals of Surgery 160:2. Supplement to 2.



surgical unit, or where extract ventilation is used, resulting in contaminated air being drawn in from anaesthetic rooms or frankly dirty rooms. Only in a very few instances has evidence been available in support of air being the vector in the transmission of hospital-acquired infection <sup>23)</sup>.

The general impression of recently published studies is that staphylococci of the type responsible for postoperative infection were rarely found in the air.

Langmuir <sup>24)</sup> has summarized: it is a safe generalization to say that the more carefully controlled the experiment, the less impressive has been the evidence in favour of airborne infection.

Despite an increasing wealth of information an authoritative microbiological standard for use in surgical theatre does not exist, partly because of lack of standard sampling methods, but rather because of absence of epidemiological data determining the role of air in the transmission of infection.

Until this is achieved, it is exceedingly difficult to justify spending large amounts of money and effort on eliminating all the bacterial content in the air supply and completely controlling air movement in surgical centers dealing with traditional surgery. There is little point in such attempts if the staff do not exercise minute control over their own movements and behaviour.

In limited fields, like transplantation surgery, where one of the prime conditions for success is sterility of the operation, a different view is to be adapted.

A high order of cleanliness is required in all surgical centers.

As the patient proceeds through the complexity of surgery the requirements on the environmental cleanliness and character vary. So do the requirements of the various members of the surgical staff. Different standards of general cleanliness as well as different levels of aseptic technique have to be accepted.

To simplify the planning process and later on to guide the staff, it has been recommended to divide the area of the surgical center into zones, classified

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23) e.g. Kinmonth J B, Hare R, Tracy G D, Thomas C G A, March J D and Jantet G H: Studies of theatre ventilation and surgical wound infection. 1958, *British Medical Journal* 2:407.

Laurell Gunnar: Nosokomiala infektioner. II. Luft- och dammsmitta. 1960, *Nordisk Medicin* 63:37-67.

Bernard H R and Cole W R: Bacterial air contamination and its relation to postoperative sepsis. 1962, *Annals of Surgery* 156:12.

Mortimer Edward A, Wolinskij Emanuel, Gonzaga Antonio J and Rammelkamp Charles J: Role of airborne transmission in staphylococcal infections. 1966, *British Medical Journal* 1:319-322.

Oviatt Vinson R: Setting standards for air in operation rooms. 1967, *Hospitals* 41:18:103-106.

24) Langmuir Alexander D in 1966, *Bacteriological Review* 30:674.



in accordance with the hygiene policy adapted by the individual hospital administration.

The idea of zoning »bloc opératoire», then mainly on the basis of assumed high degree of risk of contaminated air, was actualised in the 1930's in a mood of bacteriological idealism when complicated designs were developed, particularly in France.

For the time being at most four zones (3, 2, 1, 0) might be used. In these zones the least clean spaces have been designated as hygienic zone 3. The site of actual surgical incision, is recognized as the ultraclean zone 0. This zone is spread over an area of about 1 m<sup>2</sup>.

The classification is at some points not clear-cut as functions overlap. It is important that ample space for all functions and dysfunctions is allowed.

The zones have their own patterns of behaviour, cleanliness and protective clothing and should be distinguished one from another by different colour schemes to influence the behaviour pattern of the staff.

### *Hygienic zone 3*

so-called unclean corridor within the surgical center

waiting room for relatives

cloakrooms for street clothes

reception office

plaster room

office

records room

room for preparation

pathological laboratory

store for non-sterile materials

changing room

doctor's office

pantry

repair shop

photographic laboratory

developing room

cleaner's room

disposal room

central soiled linen room

incineration room

porter's room

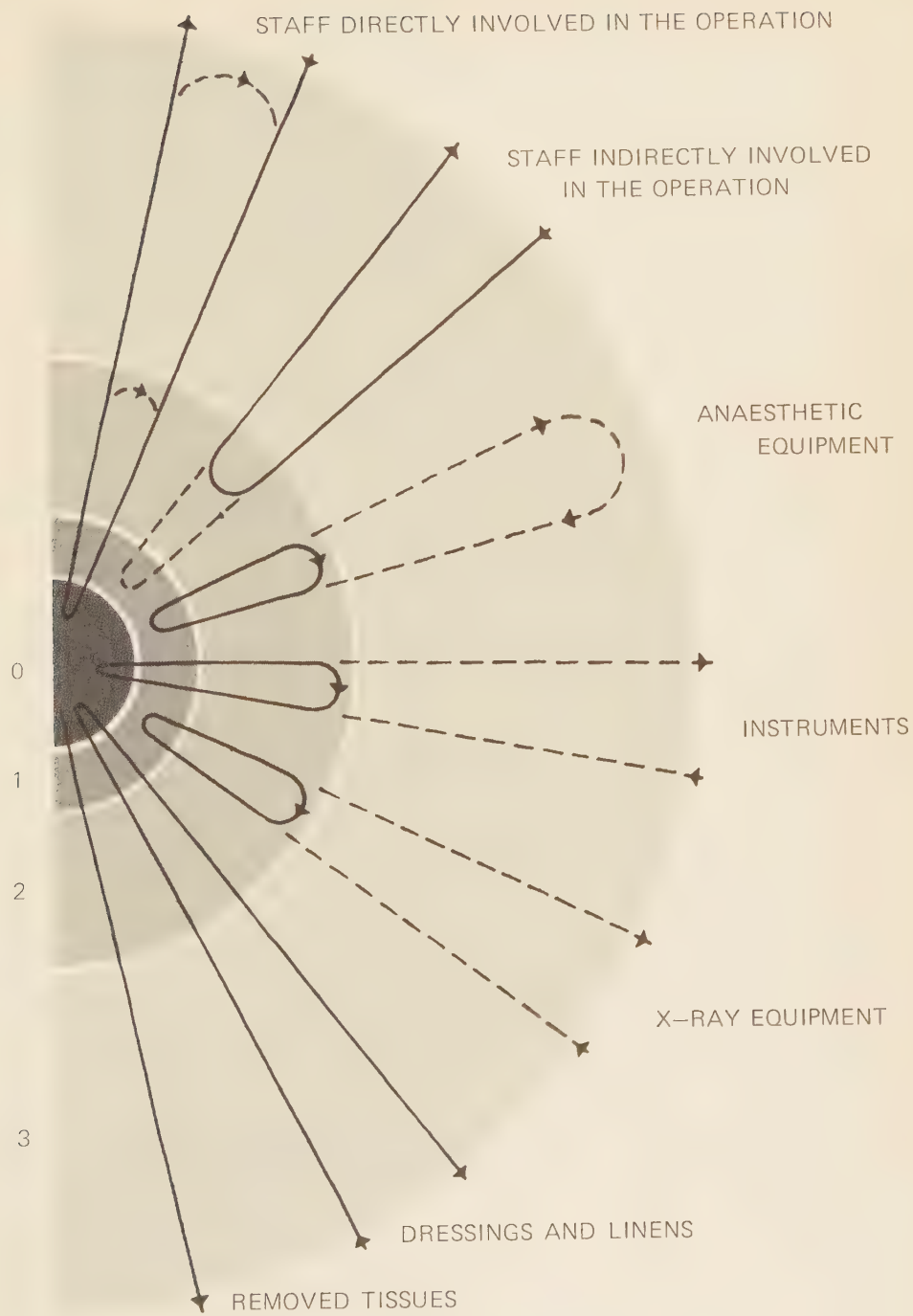
cleaner's room

toilet

### *Hygienic zone 2*

reception ward within the surgical center

so-called clean corridor



INTERZONAL MOVEMENTS

- anaesthetic room
- endoscopy room
- stores for medical gases, blood, medicine, sterile parenteral solutions etc.
- sterile service area
- rooms for the maintenance of anaesthetic apparatus
- apparatus store
- clean bed store
- general postanaesthetic room
- rest room
- staff lounge — refreshment room

### *Hygienic zone 1*

- scrub-up and gowning area
- operating theatre
- theatre clean store
- sterile linen store
- special (thoracic) postanaesthetic room

### *Hygienic zone 0*

- the site of the surgical incision

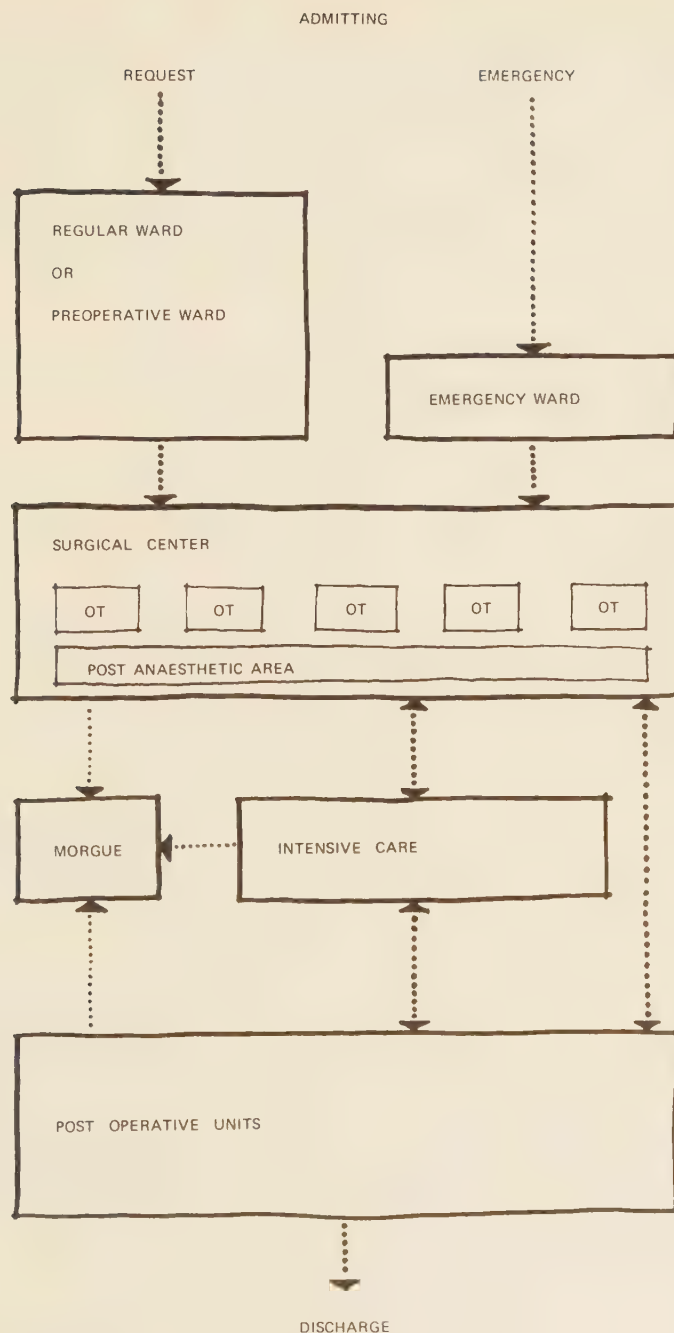
A division into hygienic zones can give a lead in the determination of the relative positions of rooms with particular regard to hospital hygiene.

For example: where one has an anaesthetic room on one side of a corridor with through-traffic and operating theatres on the other, the transport of patients from the anaesthetic room (zone 2) to the operating theatre (zone 1) must cross the so-called unclean corridor (zone 3). This is undesirable. So is the situation, where the surgeon, having scrubbed-up, must cross a circulation route to reach the theatre.

The arrangement of spaces and equipment to conform to a zoning system, is to be based on requirements of functions and governed by traffic flow. For a plan to be effective the following must be known:

- the progression routes of staff, patients and supplies
- the technique adopted for asepsis
- the methods of hygienic environment control.

When the activities of the surgical center nursing staff were analyzed <sup>25)</sup>, most proved not to be simple repetitive tasks. The largest single item, still not amounting to more than 10 per cent of nursing time, was the handling of instruments, sutures and sponges during surgery. Tasks of major importance included transporting the patient to the operating theatre, adjusting the position of the patient, preparing the surgical field and assisting the surgeon with the operation.



*FACILITIES OF A TOTAL SURGICAL SERVICE IN A FLOW CHART DIAGRAM AFFECTED BY FLUCTUATIONS IN PATIENT LOAD.*

The main progression routes to-day can be identified as follows:

*Patients:* regular ward or intensive care unit or emergency unit — holding area — anaesthetic room — theatre — anaesthetic room — postanesthetic recovery room — regular ward or intensive care unit.

*Surgical staff:* entrance — changing area — scrubbing and gowning area — theatre — rest room and/or changing area — exit.

*Other staff:* entrance — changing area — working areas — rest rooms and/or changing area — exit.

*Clean equipment and supplies:* entrance — supplies area — point of use.

*Sterile equipment and supplies:* instrument center — theatre storage — point of use.

*Dirty equipment and supplies:* point of use — disposal area — laundry or destruction unit or laboratories or sterile service, alternatively: point of use — theatre storage — sterile service or CSSD.

For evaluating traffic generally, the following factors are of consequence: number of personnel passing between any two positions, the volume of transported material and the nature of the transport. However, to reduce these factors in a surgical center to a basic mathematical value seems not to be practical and the idea is not further developed.

An appraisal of the role of space planning and particularly the idea of zoning proves to be a very complicated and indeed impracticable task, not least because exceedingly little is known about the actual effect of the layout and figuration of the surgical center on the likelihood of patient's wounds developing sepsis.

In a survey carried out by Edmunds, Drummond, Chalmers, Gillie, Whitelaw, Train, Paterson and Spence <sup>26)</sup>, it was found that pus was produced in 9.0 per cent of clean and potentially infected operation wounds in a recently built general surgical unit. The corresponding figure for a second unit housed in an old building was 9.9 per cent. Also Gillquist <sup>27)</sup> found that the over-all postoperative infection rate in a large Swedish general hospital was only reduced from 4.5 per cent to 3.6 after moving to elaborate new premises. The difference in the infection rates were statistically insignificant in both cases.

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26) Edmunds P N, Drummond W, Chalmers T S, Gillie T A, Whitelaw R G, Train T S R, Paterson W I and Spence A J: Sepsis in three Scottish non-teaching hospitals. 1965, Scottish Medical Journal 10:209-214.

27) Gillquist Jan: Sårinfektioner på en gammal och en ny operationsavdelning. 1967, Läkartidningen 64:1216-1225.



As there is a multiplicity of causes as to postoperative infections, which require a multiplicity of protective measures, the introduction of a single precaution will rarely have any effect on the infection rate.

The wound sepsis rate resulting from infection during a surgical procedure could be estimated only roughly, so the influence of additional refinement in technical and architectural principle is probably no more than marginal, and most likely could never be evaluated.

Of the errors which became evident during this study, poor space planning in shape of underdimensioned rooms is one of the most prominent. Allowances have to be made for the ever-in-motion character of man, his natural patterns of flow and motion as well as for his psychological and social interaction with others and his psycho-physiological requirements.

It is far too little to determine only the needs of a static figure or a figure group.

The space planning must provide due allowance to a simultaneous traffic pattern for the circulation of the functionally different members of the staff of the surgical center, ensuring that unnecessary movement and mutual hindrance is avoided.

### Staff area

The number of staff in the operating theatre should be strictly limited to what is needed for the operation in hand.

Any visitors — and the number should be kept minimal — as well as maintenance staff and similar groups must observe the same behaviour and practice of changing as the surgical team.

As a dominant means to control the dispersal of bacteria from the staff's body surfaces and hair *protective clothing* in the operating theatre has been used.

For the most part the conventional surgical gown worn over street clothes does little or nothing to prevent the escape of bacteria from the body to the air <sup>1)</sup>. Neither is the escape of organisms much, if at all, reduced by replacing street clothes with freshly laundered porous basic operating theatre garments worn under the gown <sup>2)</sup>. In addition, there is evidence that bacteria pass directly from the surgeon's skin to the patient wound through the sleeves of conventional surgical gowns <sup>3)</sup>. The contamination of the operative field by the passage of the bacteria dispersed by the surgeon through wet surgical linen in cases where impermeable aprons were not worn, has been reported <sup>4)</sup>.

Efforts have been made to improve the state of operating theatre dress. According to Bernard, Speers Jr, O'Grady and Shooter <sup>5)</sup> the shedding of bacteria can be almost completely eliminated by wearing a dress made from an impermeable substance such as

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1) cf also Duguid J P and Wallace A T: Airborne infection with dust liberated from clothing. 1948, The Lancet 2:845-849.

2) Baldwin Maitland, Weatherby R J and McDonald F D S: Microbial characteristics in a neuro-surgical environment. 1965, Hospitals 39:5:78.

3) Devenish E A and Miles A A: Control of Staphylococcus aureus in Operating Theatre. 1939, The Lancet 1:1088.

4) Propst H D: The effects of bactericidal agents on the sterility of surgical linen. 1953, The American Journal of Surgery 86:301-308.

5) Bernard H R, Speers Jr R, O'Grady F and Shooter R A: Reduction of dissemination of skin bacteria by modification of operating-room clothing and by ultraviolet irradiation. 1965, The Lancet 2:458-461.

polyethylene. Since the long-continued wearing of such a dress would ordinarily be intolerable, tightly woven cotton is recommended instead <sup>6)</sup>. The importance of closing the trousers openings at ankle level has been stressed <sup>7)</sup>. Closure of neck and arm openings and wearing a one-piece dress cause no comparable reduction to occluded trousers. To check unauthorized visitors it may be found suitable to reserve a certain colour, for example yellow or blue, for protective clothing to be worn only within the surgical center. This implies that theatre staff should not leave the center dressed in their protective clothing. A further distinction can be made through the use of different coloured clothing for the staff in different areas of the surgical center.

Although a *surgical mask* may actually accumulate organisms, and then discharge them in bulk on talking or coughing and the usual type of surgical gauze mask has been shown to be highly inefficient and possibly an infection hazard <sup>8)</sup>, the studies validate the concept of using a face mask to protect the open surgical wound from the potentially pathogenic nasopharyngeal microorganisms, providing a worthy mask is worn.

The key characteristic of a surgical mask remains its filtering efficiency. Without this the entire concept of wearing a face mask for the protection of the open surgical wound can be drawn into serious question. Attempts have been made to develop more efficient masks, even overall masks that provide complete head and partial neck covering.

The tests on common types of masks made from cotton, linen, paper and plastic indicate that all masks achieve a satisfactory reduction in direct droplet-infection of the operative field, the best protection being given by a linen mask <sup>9)</sup>. Rubbo and Abbott <sup>10)</sup> have examined different types of surgical masks for their efficiency and found gauze masks to be less than 30 per cent efficient as filters of airborne particles less than 5  $\mu$  in diameter. Paper and polyester-rayon materials were approximately 30 to 40 per cent and glass fibre materials almost 100 per cent efficient.

To diminish contamination via the mask, all unnecessary conversation in the surgical theatre should be prohibited, although careful studies of carriers have failed to show that normal talking throws out much *Staphylococcus aureus* <sup>11)</sup>.

Up to now skin bacteria escaping through punctured *gloves* have been included in the list of agents with high potential for causing postoperative wound infections <sup>12)</sup>. There are different views on this issue. From a study by Gad <sup>13)</sup> it would appear that there is little if any connection between glove punctures, the flora of disinfected skin and wound infection. Tindal <sup>14)</sup> has suggested that bare hands, well washed and antiseptically oiled might be safer than gloved hands. 'Gloves, however, can protect the surgeon against jaundice.

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6) cf also: Bernard Harvey R, Cole William R and Gravens Daniel L: Reduction of Vetrogenic Bacterial Contamination in Operating Rooms. 1967, *Annals of Surgery* 165:609–613.

7) Blowers Robert and Mc Cluskey Maureen: Design of operating room dress for surgeons. 1965, *The Lancet* 2:681–683.

8) cf also Hirshfeld J W and Laube P J: Surgical Masks: an Experimental Study. 1941, *Surgery* 9:720–730.

9) Linder F: The control of wound infection. in *Wound Healing*. ed by Sir Charles Illingworth. J & A Churchill Ltd. London 1966, p. 141.

10) Rubbo Sidney D and Abbott Lyndal R: Filtration Efficiency of Surgical Masks: A New Method of Evaluation. 1968, *The Australian and New Zealand Journal of Surgery* 38:1:83.

11) cf also: Shooter R A, Smith M A and Hunter C J W: A study of surgical masks. 1959, *The British Journal of Surgery* 47:246.

12) cf also: Shooter R A: Infection in Hospitals. 1966, *Abstracts of World Medicine* 39:267.

13) Gad Palle: Glove Damage as a Route of Wound Infection. 1965, *Danish Medical Bulletin* 12:1:4.

14) Tindal A: Operating theatres: An anaesthetist's thoughts. 1962, *The Lancet* 2:240.

Here also aseptic washing has to be mentioned. Any efforts for it have to be assessed on its effectiveness in destroying resident bacteria.

It is very difficult to assess the importance of timing the surgical scrub. To date it has not been clearly demonstrated that the increase or decrease in scrubbing time is directly related to the incidence of postoperative infection.

The British Medical Research Council <sup>15)</sup> recommends that the surgeon should, whenever possible, use as precautions handscrubbing with an antibacterial detergent preparation and wear gloves.

Instead of sometimes suggested overshoes *protective shoes* <sup>16)</sup>, should be used and be put on in a space reserved for that purpose outside the changing room.

As a further means to suppress the number of bacteria shed by the staff in the operating theatre Hyde-Jacobs Jr <sup>17)</sup> has recommended that a *shower-bath* be taken before dressing in protective theatre clothes. This thought is supported by Bethune, Blowers, Parker and Pask <sup>18)</sup> who have shown that more staphylococcal dispersers are made safer than are made dangerous by the shower-bath. This issue, however, remains unclear. According to Williams <sup>19)</sup> there is no evidence that a shower-bath effects any reduction in the number of staphylococci shed through clothing during the succeeding three hours so spent in the theatre. Other findings are even more negative indicating that a shower temporarily increases the number of bacteria shed by the bather. The effect is most pronounced between 10 and 45 minutes after showering and usually ceases within one to two hours <sup>20)</sup>. Blowers <sup>21)</sup> states that there is no certain way of permanently clearing *Staphylococcus aureus* from the bodies of people who carry it.

If the skin flora of the hand can be suppressed, certainly body flora can be similarly reduced. Riemensnider <sup>22)</sup> has shown that microbial shedding could be reduced by a daily routine of bathing with a germicidal detergent.

Showers are, however, needed for the staff after the operating session is finished for comfort and social reasons.

## Changing area

Staff and service personnel as well as patients should enter at the same point, which should be so located as to discourage unauthorized entry. It is essential to prevent the eventual supplies entrance being used by the staff as a back door to the department.

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15) Aseptic methods in the operating suite. 1968, The Lancet 1:705-709.

16) cf also Regamey R H and Garcia J M: Problemes poses par l'hospitalisme dans un service de chirurgie. 1966, Pathologica et Microbiologia 29:553-557.

17) Hyde-Jacobs Jr Robert: Basic studies for the planning of surgical service facilities. New York Chapter. The American Institute of Architects. New York 1963. Reprinted from AIA Journal (August, September, November 1962).

18) Bethune D W, Blowers Robert, Parker Michael and Pask E A: Dispersal of *Staphylococcus aureus* by patients and surgical staff. 1965, The Lancet 1:480-483.

19) Williams R E O: Sources and Routes of Infection. in Operating Theatres and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 9.

20) Speers Jr R, Bernard H R, O'Grady F W and Shooter R A: Increased dispersal of skin bacteria into the air after shower-baths. 1965, The Lancet 1:478-480.

21) Blowers Robert: Control of Infection from *Staph. aureus* carriers. in Research in Burns. ed by A B Wallace and A W Wilkinson. E & S Livingstone Ltd. Edinburgh and London 1966, p. 501.

22) Riemensnider D K: Reduction of microbial shedding from humans. 1967, Contamination Control 6:8:19-21.



Each *changing area*, near the entrance to the surgical center, should comprise two divisions: cloakrooms for removing and donning street clothes and rooms for changing to and from theatre clothing.

*Cloakrooms* for street clothes may be common to both male and female staff, students and visitors. Equipment should include fixed hangers, hat and shoe racks and personnel lockers.

In this area should be found bulletin and notice boards to display theatre lists, rosters and particulars of additional cases.

An adequate number of toilets — to be used before entering the changing rooms — should be provided near to the cloakroom.

To avoid contamination of operating theatre clothes, the *changing rooms* should be divided into clean and less clean areas. All ordinary clothing should be removed in the less clean area before putting on theatre clothes. In the clean dressing area, theatre clothes and caps — stored in protective containers — are donned, and from there one enters an area of a higher hygienic standard.

The changing rooms for female and male staff respectively may be further divided to suit different groups of staff, e.g. groups of six to twelve persons in a unit equipped with its own wash-basins and showers. The showers should be large enough for people to undress and dry themselves within the compartment. Showers other than those in the changing rooms should not be necessary.

The changing room should be provided with a telephone and intercom.

When the staff, students and visitors on completing their theatre work return to the less clean part of the changing area they have to place their used protective theatre clothes in hampers. These are placed in vacuum-driven disposal chutes or kept in the theatre disposal room and, on the completion of the operating session, are removed from the surgical center.

Adjacent to the changing rooms and on the theatre corridor side there should be a passage provided with wall hung foot-manoeuvred emergency *toilets* and wash basins.

#### Scrubbing and gowning area

All those taking a direct part in the operation have to disinfect their hands and arms followed by an immediate powdering or oiling of the hands. Sterile towels are used for drying.

Sterile gowns, caps for completely covering the hair and even the beard, masks and gloves, if used, should be donned in the *scrub-up room*. If it is likely that the gown may become wet with blood or other fluid, a surgeon should wear a sterilized plastic apron.

The assistance of a second person is needed in donning the operating gowns currently used. If the ties and tapes on an operating gown were eliminated



members of the operation team would not have to wait for assistance. An area of 3-4 m<sup>2</sup> is required for donning the gown.

The scrub room should be adjacent to the theatre, but physically separated from it as the aerial spread of contamination from the scrub areas to the operating room has been documented <sup>23)</sup>.

Before an operation two or three persons will wash simultaneously. The scrub room should be planned so that washing and gowning activities may proceed simultaneously without detriment to either activity. Automatic dispensers for sterile nail brushes can be used.

Space is to be reserved for a storage trolley (sterile gowns, caps, masks, aprons, gloves).

A scrub and gowning room to serve one theatre equipped with three wash-places requires an area of about 11 m<sup>2</sup>.

#### Staff lounge — refreshment room

*Staff lounge — refreshment room* ought to be comfortably furnished and well ventilated for the benefit of nonsmokers. A *pantry* with a refrigerator should be available.

It is unlikely that more than half the staff of the surgical center will be free at the same time, so the room is to be designed to hold this proportion of the staff plus some visitors.

#### Sleeping rooms

*Sleeping rooms* for surgeons, anaesthetists and nurses have to be provided within larger surgical centers as a part of the emergency service.

#### Offices

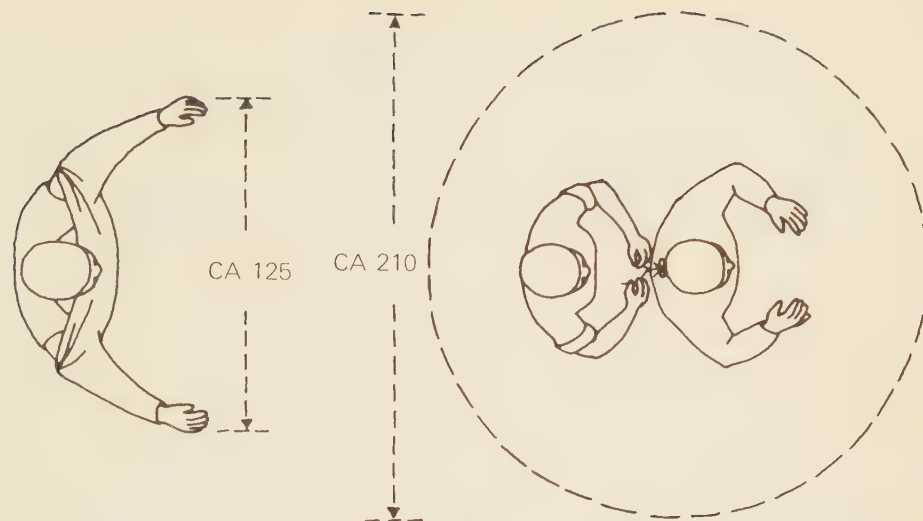
Surgeons and some others of the medical staff need *individual offices* within the center for dictation, writing and typing of records, discussions, study and rest. These offices may be split into cubicles of about 5-6 m<sup>2</sup>.

The (nurse-) supervisor responsible for the surgical center is accommodated in a *centrally located office* with an area of about 12 m<sup>2</sup>. This ought to be adequate to contain desks, table, charts, bulletin boards, shelves and filing cabinets. It is essential that *another room* outside the surgical center be provided where the supervisor can interview staff in private and talk with sales representatives and other visitors.

The clinical teacher or operating room inservice instructor for student nurses in a surgical center is essential. Although the facilities of the operating room are needed in some teaching situations, others require the atmosphere of the formal classroom. A *large office* of about 20 m<sup>2</sup> with a bulletin board and blackboard or *classroom* should be provided for this purpose. A classroom could be used also as a TV-viewing room.

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23) leRiche W Harding, Balcom Carolee E and van Belle Gerald: The Control of Infections in Hospitals. University of Toronto Press. Toronto 1966, p. 74.



*SPACE NEEDED FOR GOWNING*

*Offices for clerks* adjacent the surgical center for typing medical records should be furnished with desks, shelves, chairs, filing cabinets, telephones and intercom. The size required is about 12 m<sup>2</sup> per room.

In a large surgical center an office of about 10 m<sup>2</sup> for the *photographer* is needed.

## Preoperative area

A break in the aseptic barrier surrounding the surgical center occurs when the patient arrives from the grossly contaminated ward. So the risk of transferring contamination is to be reduced to a minimum.

The patient on the way from the ward to the surgical center should be provided with freshly de-contaminated bedding. If this is not done, clothing and blankets brought from the ward should be discarded in the holding area, where collection facilities should be provided. Even the ward staff should not proceed beyond that point.

On arrival at the entrance to the center, the patient's identity must be checked. During the stay in the holding area the patients must remain under supervision.

The *reception room* in the holding area should be equipped with a writing desk, telephone, intercom, wash basin and temporary seats for the porters. The recommended floor area is about 8 m<sup>2</sup>.

The *waiting space* required can be reckoned at one bed cubicle of 7 m<sup>2</sup> per operating theatre. For patients with diagnosed staphylococcal sepsis a separate holding room should be provided, as they may heavily contaminate the environment within a few hours of admission <sup>24)</sup>. Even patients with respiratory tract infection may heavily contaminate the surroundings <sup>25)</sup>.

A separate reception and resuscitation area to which patients will be taken before undergoing emergency surgery is a necessity.

It is bacteriologically improper to allow the patient's bed, which comes from the ward, to enter the operating theatre. It is considered satisfactory if the ward bed is kept in a holding area. The patient is transported within the center on a stretcher bed belonging to the surgical center. The patient can remain in this stretcher bed during the immediate postanaesthetic period and even during his stay in the intensive care unit.

In order to reduce the bacterial flora on wheels, it has been recommended that heavy apparatus and vehicles carrying patients during transfer to the theatre should pass over foam rubber or plastic mats saturated with detergent germicides placed on the floor or in matwells in the corridor floor at the surgical center entrance.

Experiments with shallow floor baths to act as decontaminants for wheels and even footwear show that the floor soon becomes moist and slippery.

At one hospital <sup>26)</sup> swabs of trolley wheels were taken before and immediately after traversing the antiseptic mats containing 5 per cent phenol. The swabs taken from the wheels both before and after yielded growths of the same organisms: coagulase-negative staphylococci, diphtheroid bacilli and aerobic sporing bacilli. No anaerobic organisms were found. This seems not unexpected as antiseptics do not give an instantaneous kill. The advantages of the antiseptic mats are restricted to moistening the wheels and thus preventing the dispersal of some dry dust and thus some bacteria, which makes the mats hardly recommendable.

Special *waiting rooms for children* and accompanying mothers should be provided. No instruments or apparatus need to be visible and appropriate decor may be used to reassure and interest the child. Uniforms make all nurses look alike. What a child needs is some kind of recognisable individual. In America nurses in children's wards have worn their own clothes with remarkable results. Margaret Henderson <sup>27)</sup> has maintained that so far as known observations went, sick children rarely, if ever, notice the kind of decor — woodland scenes with animals and traditional characters — which adults imagine appeals to them. Attempts should be made to avoid unnec-

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24) Turner G C, Watson D C and Abbot J D: An isolation ward for patients with staphylococcal sepsis. 1965, *The Lancet* s:426-429.

25) cf also Rountree Phyllis M and Bulteau V G: Hospital infection with tetracyclineresistant haemolytic streptococci. 1965, *The Medical Journal of Australia* 2:447.

26) Nuffield House, Musgrave Park Hospital, Belfast. *The Case History of a New Hospital Building*. London 1962, p. 164-165.

27) personal communication: Barbara Duncum Ph D, London.

essary strangeness. Reassuring decor more probably is what looks a little like school — if not like home, which would be asking rather a lot of a hospital.

Taped music helps to divert and tranquilize many children.

An attendant whose time is devoted entirely to playing with, talking to or comforting a particular child through the immediate preoperative period is essential.

The children's waiting area must be forbidden to all traffic, and extraneous conversation should not be allowed to impinge upon it.

Surgical center *corridors* should be wide: not less than 3.0 m, preferably 3.5 m.

#### Immediate preoperative ward unit

Patients undergoing elective surgery may be taken for premedication under the care of the anaesthetist to an *immediate preoperative ward* unit within the surgical center one or two hours prior to their operation. This ward is considered to be a proper place for administering a mixture of antimicrobial agents before the expected time of operation in case of potentially contaminated cases<sup>28)</sup>.

This arrangement reduces urgency in transferring the patient from the regular ward unit. Unfavourable factors in the patient's condition — e.g. an upper respiratory tract infection or a circulatory disturbance, could be more readily detected and consequently the operation postponed until the trouble has been dealt with<sup>29)</sup>. Also Martin<sup>30)</sup> recommends a preoperative unit, but he feels that not all patients are acceptable for admission and mentions especially the group of multistage orthopaedic patients.

The immediate preoperative ward is generally criticized by Essex-Lopresti<sup>31)</sup>, who feels that clinically there can be little benefit in placing the patient under the care of specially trained nursing staff before operation. The prime need then is for tranquillity. This, Essex-Lopresti feels, is less likely to be achieved in a ward where other patients are being prepared for the theatre and where the theatre attendants arrive at frequent intervals to collect patients.

In an open ward there is indeed a possibility of spreading infection. Cases with an unsuspected respiratory tract infection may contaminate the ward

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28) cf also Bernard Harvey R and Cole William R: The prophylaxis of surgical infection: The effect of prophylactic antimicrobial drugs on the incidence of infection following potentially contaminated operation. 1964, *Surgery* 56:1:151-157.

29) cf also Douglas D M: Operating-Theatre Design. 1962, *The Lancet* 2:163-169.

30) Martin John T: Role of the Anaesthesiologist in Hospital Design. 1966, *Anaesthesia and Analgesia* 45:535-540.

31) Essex-Lopresti Michael: The Anaesthetist and Theatre Planning. 1963, *British Journal of Anaesthesia* 35:649-653.



heavily in a few hours. The patients in a preoperative area should therefore be harboured in separate, elaborately equipped cubicles.

An *anaesthetic room*<sup>32)</sup>, also called a preparation room, is a space for the transfer of the patient to the operating table and for the commencement of anaesthesia, intubation, the introduction of sterile parenteral solutions, the introduction of instruments for preoperative tests etc. In this room anaesthesia is also terminated. Here the patient should be prepared and shaved or depilated with a depilatory cream, as this should be done as near the time of operation as possible.

To wheel the anaesthetised patient on the operating table and anaesthetic equipment from the anaesthetic room to the theatre requires the services of two or three persons for approximately half a minute. This time lag in started anaesthesia is considered by some anaesthetists as a theoretically possible point of danger.

In spite of that, the practice of anaesthetising the patient in the operating theatre itself, though sometimes advocated, should be considered unacceptable<sup>33)</sup> and an anaesthetic room favoured<sup>34)</sup>.

There are strong psychological reasons why anaesthesia and preoperative procedures should not be commenced in the theatre even if patients are premedicated. The anaesthetic room should be both visually and acoustically well screened from the rest of the surgical center, so that the patient is not in any way disturbed and all stimuli which are unpleasant to the patient are eliminated. The fact that heavy premedication and general anaesthesia do not prevent the patient from hearing conversations which take place in his presence or various noises while he is asleep has been well established<sup>35)</sup>.

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32) Electrical anaesthesia may change some of the requirements on the anaesthetic room.

33) cf also The Design of Operating Theatres Suites. 1964, Annals of the Royal College of Surgeons of England 34:254.

Helliwell P: Anaesthetic Rooms. in Operating Theatres and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 71.

Fulton John C: The Modern Operating Theatre Suite. 1965, Hospital's Association Journal 34:6:13.

Hercus Victor: Operating Theatre Design. 1965, Hospital's Association Journal 34:7:19.

Geissler Dieter H: Das Operationszentrum am Uebergang einer Strukturveränderung. 1968, Medizinal Markt 16:230.

34) cf also Berry Edna Cornelia and Kohn Mary Louise: Introduction to operating-room technique McGraw-Hill Book Company Inc. New York, Toronto, London 1960, p. 6.

Norlander Olof in Anesthesiologen och sjukhusplaneringen. 1966, Opuscula Medica 11:369.

35) cf also Cheek D B: What does the Surgically Anaesthetized Patient Hear? 1960, Rocky Mt, Med. J. 57:49-53.

Cheek D B: Use of Preoperative Hypnosis to Protect Patients from Careless Conversation. 1960, Am. J. Clin. Hyp. 3:101-102.

Cheek D B: Further Evidence of Persistence of Hearing Under Chemo-Anaesthesia. 1964, Am. J. Clin. Hyp. 7:55-59.



Particularly during the stage of beginning anesthesia noises are greatly exaggerated. Even low voices and minor sounds appear loud. Great care must therefore be taken to insure that the anaesthetic room is a really quiet place while anesthesia is being started.

Anaesthetic rooms need no windows: large areas of a single colour outside a window might be reflected by the ceiling, interfering with colour values in the room; furthermore, variations in daylight from hour to hour interfere with the judgement of a patient's colour. The glare from windows may tire the eyes of the anaesthetist. For the sake of consistency of quality and intensity, artificial light is to be considered to be more satisfactory.

The anaesthetic room should not serve as a natural passage to and from the operating theatre. It has even been suggested <sup>36)</sup> that all doors be fitted with bolts so that entry is impossible after the commencement of anaesthesia.

In the anaesthetic room anaesthesia is terminated by suction of the patient's respiratory passages. The anaesthetic room also serves as an exit bay for the patient after the operation. The transfer of the patient from the operating table to the transport vehicle which can remain in the anaesthetic room during the operation, may be undertaken in the anaesthetic room.

Jean Walter <sup>37)</sup> introduced on hygienic grounds two units: *preparation room* and *anaesthetic room*. In that plan the anaesthetic room was placed as a buffer between the theatre and the preparation room. Even if preoperative procedures and commencement of anaesthesia are, as at present, combined, Walter's thought might repay study e.g. in cases of transplantation surgery.

The provision of a special *exit room*, floor area 10 m<sup>2</sup>, has been suggested <sup>38)</sup>.

Anaesthetists and other medical staff require to move around the table when commencing anaesthesia in order to put patients into the required position.

To facilitate the transfer of patient, provision should be made for the easy movement of both transport vehicle and table or top of the operating table into the anaesthetic room where they will be placed side by side. The employment of various lifting devices, whether fixed or mobile, can be advantageous to patients as well as staff. Though, as a rule, slow in operation they may be of value in the operating theatre where male staff to lift the patient is not available.

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36) Galley A H in *Operating Theatres and Ancillary Rooms*. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 81.

37) Walter Jean: *Renaissance de l'Architecture Medicale*. Imprimerie E Desfasses. Paris 1945.

38) Vetter and Vouga in Moretti B F: *Ospedali*. Ulrico Hoepli. Milano 1951, p. 80.

Nedeljkov Georgj: *Die Entwicklung neuzeitlicher Operationsräume als Folge des Fortschritts von Medizin und Technik*. Dissertation TU (West) Berlin 1958.

Douglas D M: *The Theatre*. 1960, *The Architect's Journal* 132:3403:36.

Terzioğlu Arslan: *Isveç hastahane insaati*. Manuscript. Berlin 1965.

Space is required also for writing desk, medicine cabinets, storage racks (for example screens which separate the patient's head from the surgical field, for table fittings, diathermy plates), work bench and anaesthetic apparatus, suction-pumps, one or two wash basins.

Theatres are usually equipped with one or two X-ray viewing cabinets. Bacteriological surveys<sup>39)</sup> have shown that the highest degree of contamination in the theatre itself occurs around the shelf where the patient's X-ray films and notes are laid out. Films should therefore be taken in and out of the viewing cabinets from an adjacent room, which could be the anaesthetic room.

The average dimensions  $5 \times 4 \text{ m} = 20 \text{ m}^2$  can be recommended for the well ventilated anaesthetic room in the present situation as they cover very properly the needs of the majority of the anaesthetists. For complicated thoracic and neurosurgical procedures an increase in area up to  $25 \text{ m}^2$  is likely to be required. Larger anaesthetic rooms are needed even for teaching and demonstration purposes.

In connection with open heart surgery *hypothermy* is practised. For this purpose the blood of the anaesthetised patient is cooled or the patient is put in a bath-tub filled with iced water. When the patient's temperature, taken in the oesophagus and rectum, is as low as  $33^\circ\text{C}$ , the patient is dried and transferred to the operating table<sup>40)</sup>. For this additional arrangements and space are needed.

## Surgical theatres

The surgical theatre should provide an environment of maximum comfort for both surgeons and patient with reduced risk of infection to exposed tissues during surgical procedures. The theatre should not provide for activities that can be performed outside it.

A division of theatres into septic and aseptic groups would not appear to be justified, bacteriologically or as a means to promote hygiene<sup>41)</sup>, although it

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39) Helliwell P: Anaesthetic Rooms. in Operating Theatre and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 75.

40) Björk Viking Olov: Öppen hjärtkirurgi. in 20 års medicinsk forskning. PA Norstedt & Söner Förlag. Stockholm 1965, p. 408.

41) cf also Buchanan J McK et al: Postoperative infection in a casualty department. 1961, British Medical Journal 2:1678-1680.

Williams R E O in Operating Theatres and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. 1964, Altrincham, p. 20.

Shooter R A, *ibid*, p. 38.

Riethmüller Hans-Ullrich: Aktuelle Probleme der Krankenhausplanung. 1964, Architektur - Wettbewerbe 40:7.

Ginsberg Frances: If you have the right system, these 14 steps will make any O. R. safe. 1968, Modern Hospital 110:6:130.

has been required<sup>42)</sup>. That wound is obviously contaminated in no way excuses its treatment with anything other than the strict aseptic technique and attention that would be given to a clean surgical wound<sup>43)</sup>. Aseptic operations carried out in theatres belonging to the septic group seem not to be followed by a higher infection rate than normal<sup>44)</sup>.

Greater flexibility in programming work and better hygiene obtain if all main theatres could be regarded as equally clean. The possibility of reserving theatres for certain types of septic cases nonetheless remains. Such cases include among others the removal of dressings from patients with infected burns and removing plaster casts from infected patients.

The size of the theatre depends on the number of involved staff and the amount of furnishing and mobile equipment.

The actual team for routine operative procedures varies usually between four and seven persons. The team consists of a surgeon, and anaesthetist, two assistants who help with ligatures, retractors etc., a scrub nurse who prepares sets and passes instruments as required, an anaesthetist nurse and a circulating nurse. They are assisted by radiographers, technicians and porters as well as sterilising staff and disposal staff, who often will be regarded as members of the team.

Usually the surgeon stands closer to the site of the operation: on the right side of the patient facing the patient's head. For operations on the right side of the body: appendectomy, operations on the right breast, liver, right arm, right leg the surgeon stands on the right side of the patient, facing the patient's head. For operations on the abdominal cavity above the navel the surgeon usually stands on the patient's right side. For operations on the skull, perineum etc. the surgeon stands or sits at the end of the operating table, the assistants on both sides of the surgeon. In other cases the only assistant usually stands opposite the surgeon.

In cardiovascular surgery implanting a heart requires the assistance of an over all staff of about twenty or more, including doctors, nurses, technicians and engineers.

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42) Altmeier W A: Control of Wound Infection. 1966, Journal of the Royal College of Surgeons of Edinburgh 11:280.

Burkele de la Camp and Gohrbandt according to Ludwig Grün: Zum heutigen Stand der Überwindung des Hospitalismus. in Neue Krankenhäuser in Nordrhein-Westfalen. ed. by Max L R Reisinger, Peter Steffen and Josef Marke. Verlag Paul Geyer OHG. Cologne 1966, p. 35.

Good Hans: Verhütung von Hospitalinfektionen mittels eines Systems, kombiniert mit besonders wirksamen und langdauernden Desinfektionsmitteln. 1967, Veska 31:162.

43) cf also Caswell H Taylor, Schreck Kenneth M, Learner Norman et al: A three year study of staphylococcal disease with observations on control. 1960, Surgery, Gynecology & Obstetrics 110:530.

44) cf also Gillquist Jan: Sårinfektioner på en gammal och en ny operationsavdelning. 1967, Läkartidningen 64:1220.



Operations involving transplantation of organs may require simultaneous use of adjoining theatres and a double team.

The main item of theatre furniture is the operating table. Usually operating tables on wheels are used to move patients between anaesthetic room and theatre. There are operating tables that can be detached from their pedestals which are permanently fixed to the floor. The pedestal may accommodate pipes for hydraulic power, to maneuver the table top, and gas and electricity supplies. When released from the pedestal the table top, complete with patient, fits on to a wheeled trolley for transfer between anaesthetic room and theatre. For the same pedestal there are different table tops for general, orthopaedic and gynaecological surgery.

The introduction of contour fitting tables marks an interest in rethinking design. As an aid in surgery for rare detached retina conditions suspended tables have been designed.

A traumatological operating table has been designed<sup>45)</sup> with three independent pillars, liftable and movable in several directions, which support the body of the patient. The table has also a system of pulling for the simultaneous treatment of injured limbs.

All operating tables should be so constructed as to allow the convenient insertion of X-ray cassettes.

There should not be any knobs on the table to stick into the surgeon.

When the normal position of the operating table and the head of the patient is considered it should be decided in relation to the anaesthetist's position, which should be nearest the anaesthetic room.

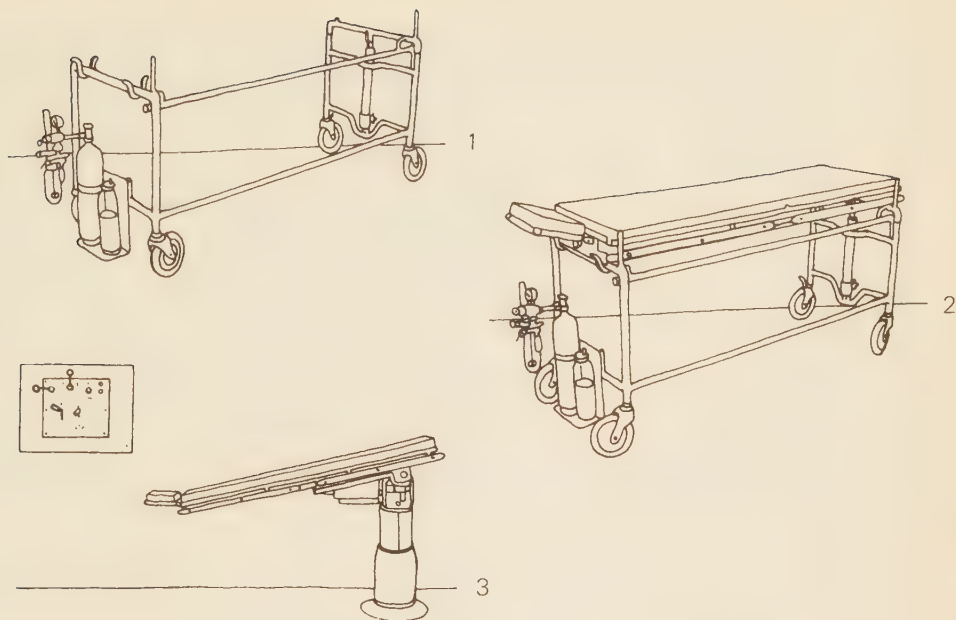
A surgical center will require one table per theatre plus reserve tables depending on the number and frequency of operations.

An inventory of mobile apparatus used in connection with operations would include anaesthetic apparatus with anaesthetic tables, X-ray machines, electro-cardiographs, diathermy machines, electrical suction pumps and acoustic pulse monitors. An increased use of respirators and measuring devices for physiological and isotope investigations, etc. may be expected.

Furnishings and equipment should wherever possible be fixed and wall hung, easily cleaned and decontaminated. Anaesthetic apparatus, operating tables, pumps, X-ray apparatus, operating lamps etc. should be provided with simple covers. Attention is directed also to the need to see that undersurfaces, wheels etc. are easily accessible for cleaning.

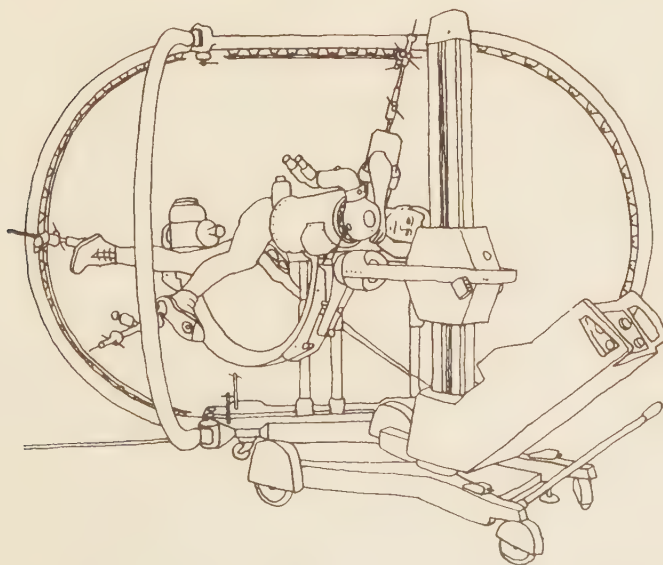
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45) Berenty George: New Hungarian Universal Traumatological Operating Table. 1968, Hospitals' Association Journal 37:1:1-4.



*THE KIFA H-SYSTEM INCLUDES A TROLLEY 1, TRANSPORTABLE TABLE TOPS 2 AND A PERMANENTLY MOUNTED BASE 3 IN OPERATING ROOM.*

*The patient is transported from bed or ambulance to surgical theatre and post anaesthetic department without changing position of patient. The table top can be firmly clamped in desired position on the base.*



*TRAUMATOLOGICAL OPERATING TABLE DESIGNED BY FERENC OBERNA.*



The absolute minimum size of the theatre for general surgery is in an area of  $5.20 \times 5.55 = 28.9 \text{ m}^2$ . In this area standard aseptic techniques could be accomplished as it includes a zone of a very high hygienic order, of about  $2 \text{ m}^2$  in size, with traffic zones around.

A suitable size for an operating theatre for most forms of surgery at the present time will be in the region of 40 to 42  $\text{m}^2$ . Variations in theatre size according to the number of staff and amount of material required for different types of operations in general surgery is not to be recommended if one seeks the natural flexibility of use.

Theatres for special branches of surgery such as neurosurgery, thoracic surgery, eye surgery, orthopaedics and ear, nose and throat surgery are now so specialised in their equipment that a certain segregation ought to be maintained. For transplantation surgery a special twin theatre suite is needed.

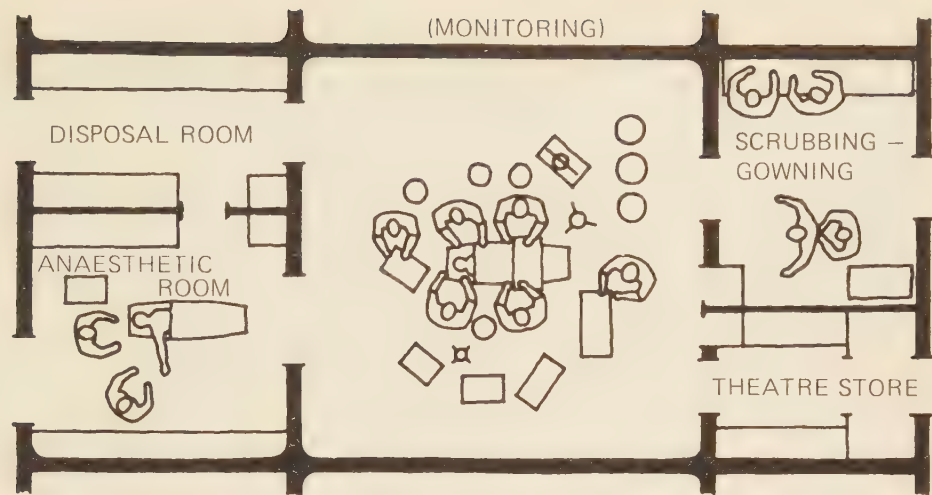
In some cases an increase of area is justified. E.g. the complexity of procedures such as cardiovascular surgery with a large staff and extra equipment involved necessitate that one or more of the theatres in a surgical center be larger e.g.  $7.5 \times 7.5 = 56 \text{ m}^2$ . This requirement is reinforced by the probability that the number of operations where two teams work simultaneously may be considerably increased.

This study recommends that the *free ceiling*, with or without a suspended ceiling, should preferably be 3.5 m and not less than 3.2 m to maintain a good volumetric proportion with people and equipment in space.

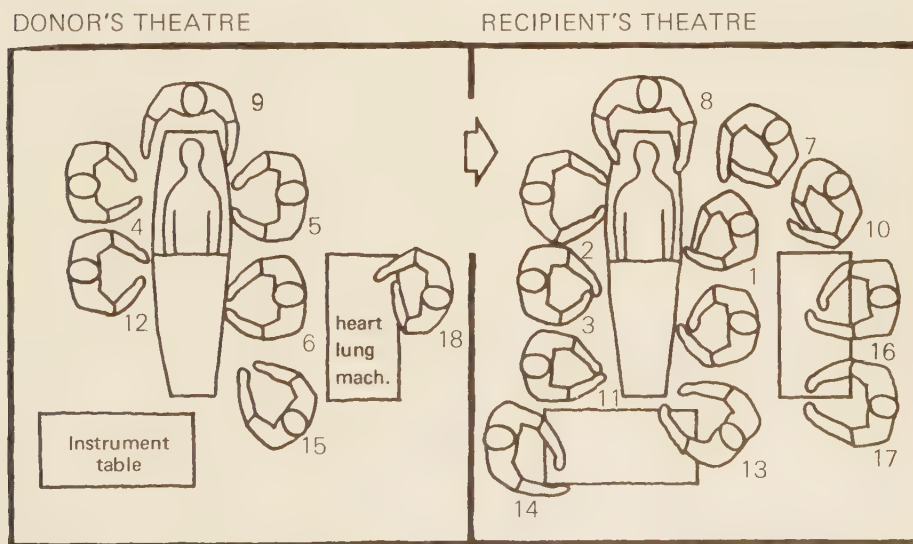
It has been suggested that shapes other than the rectangular would contribute to an improvement of standards of concentration, hygiene, and lighting. Thus during the last few decades circular, oval, dodecagonal as well as asymmetrical plans and ceiling forms have been tried.

It is highly doubtful if these shapes with their higher building costs have any real advantages over the usual rectangular theatre. A rectangular operating theatre with rounded internal corners should meet most of the present requirement.

Consistency of construction should extend to an identical shape and the very same placing of doors, outlets for electricity, medical gases, compressed air and other equipment in all theatres. Left and right handed theatres as can be found in twin theatre suites should therefore be discouraged.



*A BASIC THEATRE UNIT.*



*A RECONSTRUCTION OF THE PARTS PLAYED BY A HEART TRANSPLANT TEAM IN A TWIN THEATRE SUITE.*

1. chief surgeon 2. senior consultant surgeon 3. assistant surgeon 4. consultant surgeon 5. first surgical assistant 6. second surgical assistant 7. surgical officer 8. consultant anaesthetist 9. anaesthetist 10. haematologist 11. theatre sister 12. scrub sister 13. scrub nurse 14. sister 15. running sister 16. chief technician 17. assistant technician 18. heart-lung technician.

## Special theatres

### Endoscopy rooms

The three major groups of *endoscopy* are genito-urinary, rectal, and pulmonary. All of them are functionally well served in a room with an area of about 30 m<sup>2</sup> including all the characteristics of a surgical theatre. As large amounts of sterile water are used for irrigation purposes, a floor drain should be provided.

### Plaster room

A patient requiring a plaster support can sometimes not be moved from the operating table and must therefore be plastered in the theatre. Whenever the need can be foreseen, plastering, and especially the removal of plaster with attendant dust, should be performed in a special *plaster room*.

The plaster room, usually requiring its own anaesthetic room, should have an area of about 40 m<sup>2</sup> and be placed peripherally in the surgical center.

The design of the plaster room should take into account the contamination risk inherent in removing plasters and of the special equipment required: orthopaedic tables, X-ray apparatus, suspension frames, slop sinks with plaster traps etc.

The splint and plaster store should for preference be located between the orthopaedic theatre and plaster room.

The possible replacement of plaster by plastic materials would evidently result in modifications to the present routine.

### Clinical hyperbaric chambers

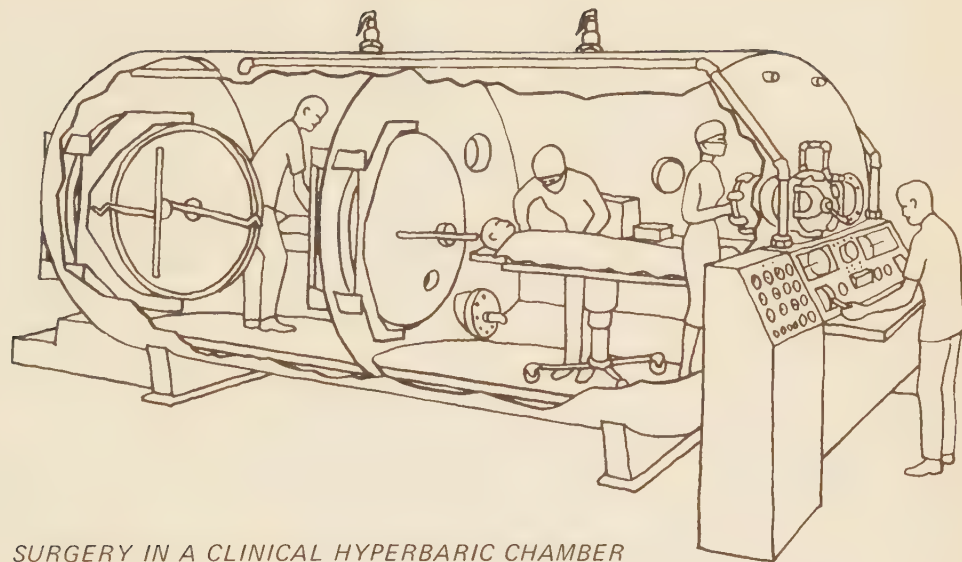
In cases where surgery is made dependent upon oxygenation, pressurized theatres or hyperbaric chambers will be necessary. Today the precise indications for its use have not been defined. Another important question is whether the *clinical hyperbaric chamber* in the current era of medical and surgical advances will prove sufficiently rewarding to justify the great cost of construction and operation<sup>50)</sup>.

A hyperbaric chamber is a double-locked chamber usually 4-15 m in overall length and 3.5 - 5 m in diameter. It is housed in a laboratory which contains a high-pressure compressor having a normal working pressure of about three atmospheres absolute, a low pressure compressor to keep circulation constant throughout the chamber, and reserve banks of the air and oxygen supply.

Within the chamber there is an air conditioner, based on filtered recirculation, a control of separate automatic regulation of pressure in each part of the chamber, a control of humidity and temperature, at least two separate means of communication, an operating table with instruments, cold and hot water, a blood-gas analysis equipment, recording equipment for measuring pressures and cardiac output, a medical lock for passing small instruments in and out of the chamber without decompression, a conduit panel to receive signals from sensors within the chamber for recorders outside and fire extinguishers.

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50) cf also Brown Jr Ivan W, Fuson Robert L, Mauney Maxton and Fand Smith Wirt W: Hyperbaric Oxygenation. in *Advances in Surgery*. Vol. I. Medical Year Book Publishers Inc. Chicago 1965, p. 339.



*SURGERY IN A CLINICAL HYPERBARIC CHAMBER*

TV monitors as well as thick laminated glass portholes and controls on the outside of the chamber allow close observation and control of conditions to be maintained inside the clinical hyperbaric chamber and information to be recorded on control panels.

Precautions to be taken in the construction of a hyperbaric chamber are similar to those taken in connection with any high pressure oxygen unit. They include explosion-proof construction of all electrical installations, uninterrupted wiring for lights, placement of all circuit breakers and electric motors outside the chamber, installation of light fixtures outside the chamber, earthing of conductive floor, and controls on air inlet and outlet lines.

Among other aspects that must be considered when planning a clinical hyperbaric unit are the colour of the chamber walls and the character of lighting which have to alleviate any feelings of claustrophobia.

For continuous operation, a noise level below 60 decibels should be attained.

To provide a germ-free and dust-free operating environment for altered physiological states needed to accomplish some goals of the contemporary surgery, plastic *isolators* have been developed<sup>46)</sup>.

46) cf also Levenson S M, Trexler P C, Malm O J, Horowitz R E and Moncrief Jr W H: A disposable plastic isolator for operating in a sterile environment. 1960, *Surgical Forum* 11:306.  
Levenson S M, Trexler P C, La Conte M L and Pulaski E: Application of the technology of the germ-free laboratory to special problems of patient care. 1964, *The American Journal of Surgery* 107:710.  
Letac R: La protection contre l'infection hospitaliere exogen en chirurgie et en petite chirurgie. 1966, *Revue d'Hygiene et de Medecine Sociale* 14:2:163-170.  
Beal Charles B, Epinosa Hernan, Sites Daniel P, Watson Milton J and Cox Dale: A surgical wound isolator. 1967, *The Lancet* 1:97-101.



The patient is put in an isolator, which is sterilised inside and contains all the instruments that the surgeons expect to use. The isolator is cemented to the patient and inflated with sterile air. Then the surgeons thrust their hands into plastic gloves that are part of the walls. They cut through both isolator and patient — the cement forms an airtight seal around the wound — and work on an incision that is isolated from contamination.

The plastic isolator might be dismissed as a device for surgery, but not on the grounds of discomfort for the surgeon. Hyde Jacobs Jr<sup>47)</sup> has found that temperature, comfort, vision, respiration and hearing were an improvement over conditions found in the common surgical theatre.

Even major surgery might be performed in the surgical isolator with exclusion of the exogenous bacteria.

Another method used to perform surgical operations in near sterile conditions is being developed by Charnley<sup>48)</sup>, who designed an enclosure suitable only for a part of the body, this time to operate on patient's hip joints. In order to reduce to a minimum the unsterile particles near the open wound, only the surgeons and his two assistants, were allowed inside the enclosure.

When the theatre had been used for about three years, the inventor stated<sup>49)</sup> that the final test of this technique on the acutal infection rate is still being studied and expected a very significant improvement to come to light.

To what extent isolators will prove practical for everyday surgery remains to be seen. They can be useful in the prevention of wound contamination where the patient is extremely susceptible to infection or in parts of the world where the regular surgical facilities are inadequate.

## Facilities for radiology, recording, monitoring, laboratories, tissue collection

### Radiology

Surgical theatre work requiring X-ray staff is usually arranged beforehand as radiology in the surgical center should remain the responsibility of the hospital radiology department. An investigation<sup>51)</sup> shows that although there is some evidence that proximity between surgical center and radiology department helps to smooth working, there is also evidence that delays nevertheless occur.

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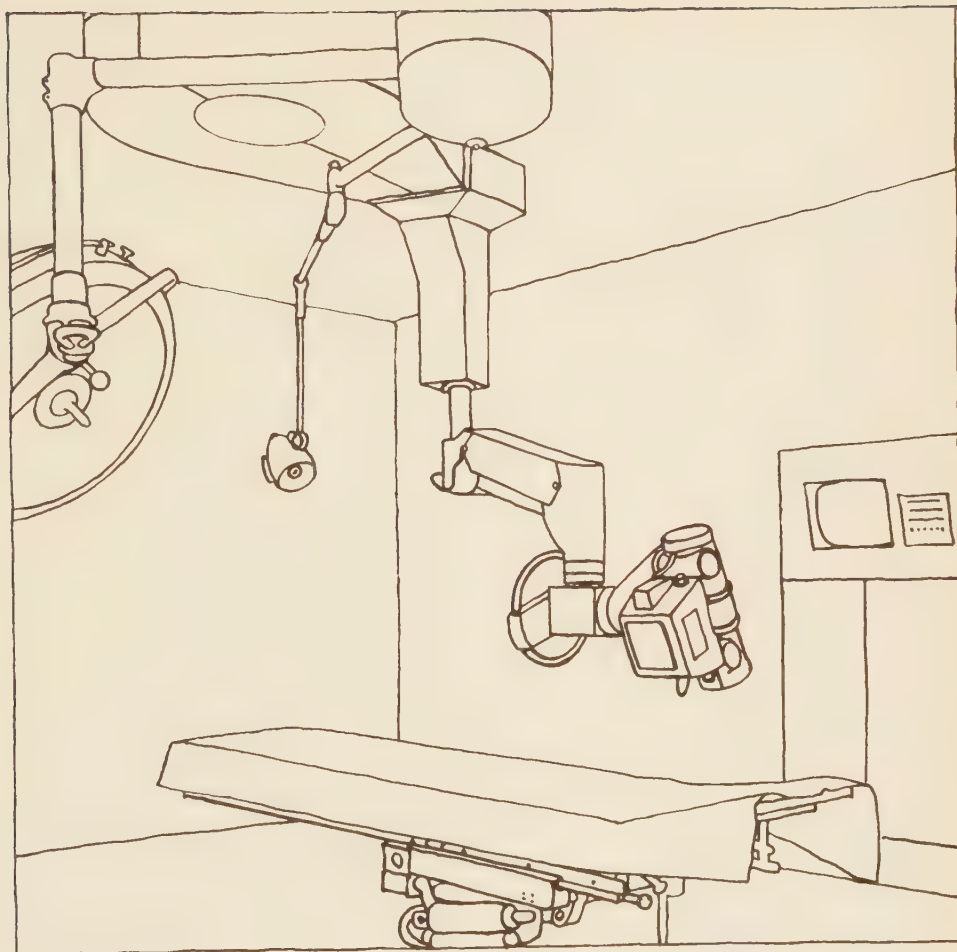
47) personal communication: Robert Hyde Jacobs Jr, New York.

48) Charnley John: A clean-air operating enclosure. 1964, *The British Journal of Surgery* 51:202-205.

49) Charnley John: Wrightington clean air enclosure for hip surgery. 1968, *Hospital Management* 31:385, supplement p. 45.

51) Towards a Clearer View. The Organisation of Diagnostic X-ray Departments. Oxford University Press. London, New York, Toronto 1962, p. 94.





Courtesy Philips

*A ceiling crane (Concentra HV) for X-ray tube. The X-ray beam can be positioned from a point outside the sterile field in different angles from vertical to horizontal. All cables are contained inside the stand.*

Radiology within the surgical center compromises the pre-operative X-rays for the guidance of the surgeon during operation, diagnostic radiology during operating and taking postoperative roentgenograms as routine in several categories of surgical patients.

In all cases of examination, it is usually necessary to provide the surgeon with diagnostic information very quickly. This presupposes the provision of good X-ray equipment and means of rapidly developing film.

X-ray equipment comprise mobile X-ray tubes in the ceiling, possibly with a common transformer and control panel, X-ray tubes in mobile frames with common transformer for several tubes, and X-ray apparatus on wheels, including tube and transformer.

Even though the guide rails of X-ray tubes mounted in the ceiling may prove difficult to clean, a considerable demand for X-ray work in a theatre will nevertheless justify their use in preference to mobile apparatus. Mobile frames may cause difficulties when connected to highvoltage current. Mobile X-ray apparatus of adequate capacity is heavy and may require servomotor assistance. Apparatus with servomotors must be protected against the risk of igniting inflammable anaesthetic gases.

A minimum requirement for a major surgical center might comprise three X-ray machines; one fixed and two mobile. Operating tables should be provided with X-ray cassette holders so constructed that none of the staff needs to remain at the table during exposures.

Technical development in the field of radiology is still so rapid that the current models may soon be superseded.

The use of X-ray television in accident surgery considerably decreases the patient's radiation charge. The surgeon obtains a clearer sight and can reduce the number of exposures of bones in the treatment of fresh fractures.

Control apparatus which is usually operated by radiologists should wherever possible be placed outside the theatre in a *control room* or in the anaesthetic room, protected against radiation, where theatre staff also might remain during X-ray exposures. When staff administering anaesthesia have to remain at the table during exposure adequate protection for them should be provided by lead-rubber aprons and gloves.

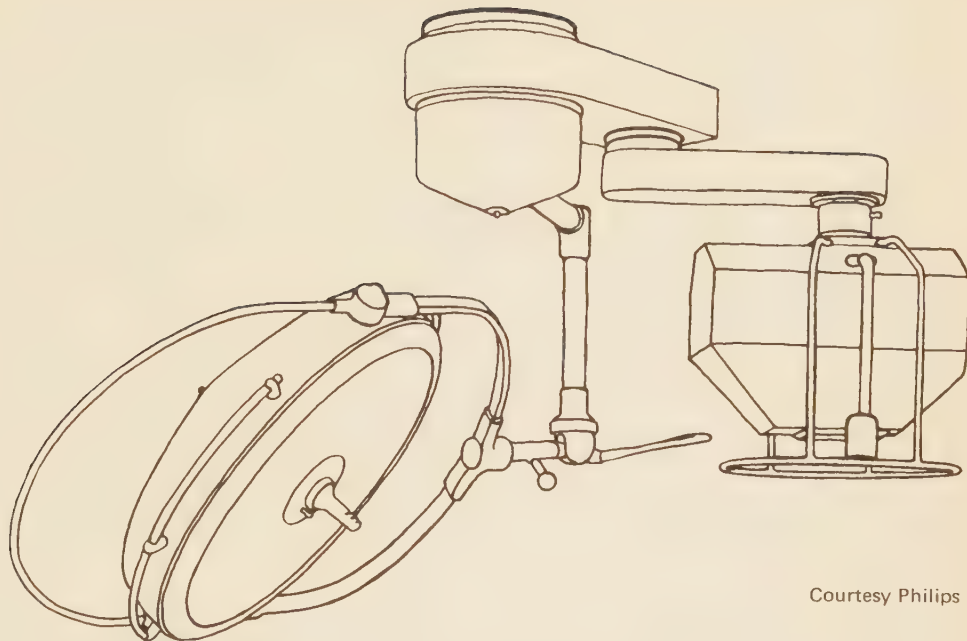
The *X-ray developing room*, equipped with storage space for cassettes and chemicals, should be well ventilated. It should have a floor area of about 10 m<sup>2</sup>.

If fixed or mobile X-ray tubes in the ceiling are not used and only X-ray apparatus on wheels is available *storage spaces* for this equipment must be planned.

#### Transmitting, recording

A closed circuit television can contribute towards a better collaboration between surgeons and radiologists.

By closed circuit television a film developed in the radiology department can be transmitted to the surgical center with a commentary by the radiologist. A pneumatic tube for sending films from the theatre to the radiology department will be needed, because the quality of X-ray films exposed in surgical center is all the better for being processed in the radiology department.



Courtesy Philips

*A ceiling crane (Concentra TV) for X-ray tube with vertical beam and fixed focus-floor distance. The vertical beam can be moved over a circular area. This crane can be mounted concentrically to the HV-crane for bi-plane TV-screening.*

ment where qualified staff and apparatus are available<sup>52)</sup>. The reverse process, the transmission by television of an exposed film from the theatre to the radiology department for the radiologist's opinion is at present considered impracticable. For accurate diagnosis the radiologist must see the original exposure.

Closed circuit television system in operating theatres usually have two circuits for vision and two for sound. One sound and one vision circuit terminate in the operating lamp, servicing the permanent camera there. A second pair of circuits terminate in a distribution panel beneath a picture monitor in the theatre and are used in combination with the complementary mobile camera. Transmissions from the operating theatre are linked to viewing rooms.

It is salutary to remember that, as was emphasised by Lord Ritchie-Calder, with all these new media of communication, first make sure that you have something worthy to communicate.

52) cf also Olsson Olle: Televisionen i röntgendiagnostisk avdelning. 1964, Svensk Läkartidning 61:1161.

At present it still seems that good quality 16 mm film (colour or black and white) cameras should be preferred to closed circuit television for recording operations. A camera may be placed in the operating lamp but should be complemented by a mobile camera elsewhere in the theatre.

A reflex-camera with flash attachment is appropriate for medical documentation work in operating theatres. Photographic equipment should be of a construction that prevents ignition of flammable gases.

#### Monitoring, computers

Monitoring devices can provide information on the basic physiological constants and variables.

It has been suggested <sup>53)</sup> that there are four basic physiological factors for which monitors offer particular advantage during anaesthesia and in the immediate postanaesthetic period: continuous monitoring of the pulse, frequent determination of the blood pressure by auscultatory means, quantitative evaluation of lung ventilation and continuous determination of body temperature. The number of the physiological factors to be monitored is being increased.

The network of electronic devices helping to ensure the safety of the patient by recording the measurement of his vitality include: atmospheric and thermal recorders, oxygen analysers which can be displayed on a kymograph, thermister bridges for multiple site temperatures e.g. patient's skin, rectum and esophagus; cathode ray oscilloscope for displaying the patient's rapidly changing physiological functions, e.g. electrocardiograms, electroencephalograms, electromyograms; blood gas tension recorders, records of drugs and liquids administered.

The apparatus should permit simple, frequent checking of results. Channels should be provided to link instruments from theatres to various laboratories. Although the use of electronic monitoring devices of various kinds in connection with surgery is becoming more common, monitoring will not be possible for all patients until equipment becomes much smaller and less obtrusive.

If the monitor is simple to apply, and the information provided is important to the welfare of the patient, its use should be encouraged. However, it can never be used to supplant the five natural senses of the anaesthesiologist and the close relationship between him and the patient <sup>54)</sup>.

Computers help to process data on patients and facilitate diagnosis based on accumulated case histories. Systems which connect a computer directly to the monitoring instrument and to body transducers linked to patients in the operating theatre may soon be available. Most monitoring systems on the

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53) Dillon John B: Monitors in the Operating Room. 1964, The American Journal of Surgery 107:595-597.

54) Stephen C R: Of Such Things is Anesthesia. 1968, Anesthesia and Analgesia 47:437.



market are not yet adequate for wholly effective monitoring of the patient's physiological state. Currently the alarms they give are based largely upon interpretations derived from analysis of a single variable, and do not have the sensitivity and flexibility for the accurate monitoring of a critically ill human being<sup>55)</sup>.

An optimal new system would necessitate a screen giving visual information as the operation proceeds. The immediate advantages would be a minute-to-minute alarm system to indicate when a patient is in physiologic difficulty and the automatic preparation of the anaesthetic record indicating blood pressure, pulse and respiration. It could be expected that this system will allow the prediction of situations in which the patient may be in difficulty, before clinical signs can be observed.

Before computer uses are considered the cost has to be investigated. The total cost of the computer system must be measured with the profits expected to be achieved in terms of saving time for the physicians, in terms of saving laboratory tests, days of hospitalization and substantial improvement of patient care.

In order to keep the theatre as far as possible clear of monitoring apparatus, which can be bulky and difficult to decontaminate, a special room of about 25 to 30 m<sup>2</sup> with glazed partition is added to the theatre. This room could be used also for the colour TV control.

Monitoring rooms may be placed above the theatre, where they share space with air conditioning plant and do not interfere with circulation.

For clinical procedures within the surgical center it will be necessary to provide the following special facilities with suitable apparatus, each with a floor area of about 12 m<sup>2</sup>:

a *biochemistry* laboratory capable of undertaking a continuous check on procedures involved, for example frequent blood gas analyses in cardiac surgery and hypothermia;

a laboratory for the preparation of *radioactive isotopes* to be administered in operating theatres and for the preparation of measuring apparatus for theatre use and for the measurement of sample tissues and fluids obtained in the theatre;

a *pathological* laboratory for quick diagnoses, including a space for frozen sections and initial preparation of all surgical pathological material.

As the installation of an efficient pneumatic tube system gives access to the main diagnostic laboratory services of the hospital there has been opinion against having subsidiary diagnostic laboratories in the center on the grounds that main laboratories should always be used.

#### Laboratory services

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55) cf also Callahan Barbara: A computer world. 1965, Hospital Progress 46:11:80.



A *bacteriological* study of every area of the surgical center should be a regularly scheduled part of the procedures.

#### Tissue bank

The function of a *tissue bank* is the collection and storage of tissue and its distribution. Here also the basic chemical and biological pattern of the tissue is determined.

The bank is organized in sections dealing with the taking of tissue and its preservation and classification.

#### Stores

Storage facilities within a surgical center should generally be divided so that the bulk stores are complemented by a sufficient number of suitably located storage trolleys.

A *central storage space* is needed for dressings manufactured and sterilized either in the factory or the hospital sterilization center and for sterile linen produced in the central laundry. The room should provide working space also for the preparation for special dressings.

*Space for the trolleys* will be needed for caps, gowns, masks, gloves, etc. in the scrub room; for dressings in the anaesthetic room, and sterile linen etc. in the theatre store.

*Medicine* and *serums* should be stored in a separate room. Cupboards for medicine in or near the theatres and anaesthetic room will be required. Medicine trolleys could be used.

Central storage for *blood*, *sterile parenteral solutions* etc. is required for reserves against urgent calls for blood and for bottles of made-up and cross-tested blood for particular patients. Sterile parenteral solutions may usually be stored at room temperature. A rotating cupboard maintaining a temperature of  $+4 - \pm 2^{\circ}\text{C}$  is needed for blood as well as a working space, where the anaesthetist can perform his own crosstest. Other blood supplies may be stored in bottles in a portable refrigerated trolley.

Supplies of *sterile water* can be located adjacent to the store for blood. At present the most satisfactory method is to sterilise water in the bottle for use in the theatre. One and two litre bottles are used. Several bottles may be stored for convenience in a heated cupboard.

*Anaesthetists' storage* space is required for replacement materials, infrequently used medical-gas tubes, apparatus, and respirators.

Storage space for *splints* etc. is best placed adjacent to the plaster room.

Storage space for *apparatus* and *bulky equipment* can suitably be divided into units of  $10\text{ m}^2$  each to serve 2-3 operating theatres.

#### Theatre store

A *room of about  $5\text{ m}^2$  adjacent to the theatre* should be provided for the storage of sterile instrument sets or trolley tops, together with emergency sets from the instrument center, syringes, operation linen and dressings in

sets, surgical sutures, tissue adhesives, medicine and sterile water bottles. In this room even trolley-laying with sterile equipment may be done.

Used, but decontaminated instruments may also be stored in this room before transport to the instrument center.

#### Storage cabinets in operating theatres

Bacteriological studies<sup>56)</sup> have indicated an appreciable reduction in the contamination of equipment and supplies by airborne organisms in closed cabinets as compared with open cabinets. During the study, nurses who used the cabinets said there was little or no delay or difficulty attributable to the opening and closing of cabinet doors. Bacterial colony counts indicated that additional air movement from opening and closing doors added very little to the total of airborne organisms. No attempt was made to ascertain whether staff handling contaminated the door knobs. It may be assumed that frequent hand washing and cleaning the door knobs would virtually eliminate this as a problem.

#### Storage space for clean beds

Patients transferred from the casualty department to the surgical center for operation may require *clean beds* after surgery. A space of 2.5 m<sup>2</sup> for each bed is needed.

Alternatively stretcher-beds could be used requiring less space.

#### Mortuary trolley parking

A space of about 5 m<sup>2</sup> is required for *mortuary trolley* parking.

### Postoperative units

#### Postanaesthetic recovery area

A postanaesthetic recovery area with arrangements for the supervision of patients has become an essential part of the surgical center, although the post anaesthetic room itself provides a field as yet relatively untouched for intensive investigation of physiological changes in the patient after anaesthesia and surgery<sup>57)</sup>.

The patient is kept in this area until his natural reflexes have returned, his blood pressure and respiration are stable and there is no more danger from the possible hazards of asphyxia, vomiting and shock and other complications requiring resuscitation.

The length of stay of each patient in the recovery area will vary according to the practice adopted by the individual hospitals, but will generally not exceed 45 minutes. The medical procedures in the postanaesthetic recovery may include intravenous drips and respiratory care. When the surgeon or anaesthetist has given permission, the patient is returned to the ward, or if necessary, transferred to an intensive care unit.

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56) Fitzwater Janet: Bacteriological Studies of Open and Closed Cabinets in the Operating Room. 1963, Hospital Topics 41:1:75-77.

57) cf also Howland William S and Schweizer Olga: The Recovery Room. in Anaesthesiology. ed by Donald E Hale. Blackwell Scientific Publication. Oxford 1963, p. 937.

The postanaesthetic unit is to be kept open round the clock and should be placed within the surgical center and on the same level as the operating theatres. It is also essential that the unit be placed adjacent to an intensive care unit.

The number of beds in the unit depends on the turnover and organisation of the surgical center. Even if the hospital has fully developed intensive care one ought to allow from 1.3 to 1.8 beds per operating theatre for postanaesthetic recovery.

A postanaesthetic unit may contain the following spaces:

- open recovery room
- isolation rooms
- room for maximum care (cases of breathing and tetanus insufficiency)
- room for induced hypothermy (+12°C)
- room for hyperbaric oxygen
- nurses' station
- disposal room
- stores for instruments, medicine, catheters, infusion fluids, linen, apparatus, oxygen tent, etc.
- changing facilities
- waiting room for relatives.

The use of suction, ECG and other apparatus may be necessary at every bedside and this requires in the open area a space of about 150 cm between beds. Floor area per bed is estimated at 10-12 m<sup>2</sup>.

The rather quick turnover of patients in a postanaesthetic unit requires the provision of large circulation areas within the unit.

For supervision of postanaesthetic beds a nurses' station rather than a separate room is to be preferred. A large postanaesthetic unit might require several nurses' stations. The nurses' station should include space for medicine cupboards and a wash basin. The unit must be connected to the hospital intercom system.

To facilitate supervision the beds are best placed in one room and they will only occasionally be screened from one another.

Patients after anaesthesia are particularly susceptible to respiratory infection<sup>58)</sup>. There are obvious risks of postoperative infections in the open wards, not at least in connection with thoracic surgery<sup>59)</sup>, therefore an ade-

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58) Winge-Hedén Kerstin: Bacteriologic Studies of Anaesthetic Apparatus. 1962, *Acta Chirurgica Scandinavica* 29:294.

59) Lindbom Gunnar: Studies of the Epidemiology of Staphylococcal Infections. 1964, *Acta Chirurgica Scandinavica* 120:430-433.

Lindbom Gunnar and Laurell Gunnar: Studies on the Epidemiology of Staphylococcal Infections. 5. Importance of Environmental Factors During the Early Postoperative Phase. 1967, *Acta Pathologica et Microbiologica Scandinavica* 69:246-263.

quate proportion of isolation rooms should be provided<sup>60</sup>). 14-16 m<sup>2</sup> should be allowed for isolation rooms, each equipped with a wash basin. These isolation rooms are to be used also in connection with infectious cases.

A separate disposal room is needed, with trapped slop-sinks, together with arrangements for the decontamination of bedpans (or destroyer for disposable bedpans and urine bottles) cleaning materials, sink, wash-basin and incinerator. For a disposal room an allowance of 8-10 m<sup>2</sup> floor area should be made.

Storage spaces should be provided close to the nurses' station.

If a desperately ill patient is held in the postanesthetic unit, humanitarian reasons may make a visit by relatives desirable. The relatives should be properly robed to enter the area. A waiting area for the relatives should be provided.

The observation of the patient's colour and breathing is of special importance in the postanesthetic unit; therefore attention should be paid both to the colour of the lighting and to the colour of the room. Light fittings should be placed where they will not disturb the patient.

Individual lights as well as connections for electrical apparatus, for oxygen, suction etc. should be provided at every bed.

With regard to the character of the room, sound absorbent floor and ceiling materials and a wall finish with a reflection factor of about 50 per cent should be chosen.

#### Intensive care units

Intensive care wards — whether they are metabolic, respiratory or for any other purpose — are to be regarded for a section of patients as an extension of the immediate postoperative care outside the surgical center.

Planning problems of the intensive care units have been discussed elsewhere<sup>61</sup>).

#### Facilities for sterilization, decontamination and maintenance

#### Instrument center and sterile service

The preparation of surgical center supplies proceeds simultaneously both in a sterile service area of the surgical center and in the central supply department.

In large surgical centers theatre instruments and some anaesthetic equipment are most suitably maintained and sterilized in the *instrument center* of the sterile service. The center is responsible for the wrapping and storage of in-

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60) cf also Wiklund Per Erik: Design of A Recovery Room and Intensive Care Unit. 1965, *Anaesthesiology* 26:667-674.

61) Pütsep Ervin and Linneroth Anna: Die Planung von Intensivpflegestationen. In *Modernes Krankenhaus 2*. Verlag für Gesamtmedizin. Berlin 1960, p. 85-104.

Pütsep Ervin and Linneroth Anna: Utformning av vårdavdelningar i samband med införande av progressiv vård. 1962, *Sjukhuset* nr 9 and 10.



struments. The center also stores items from pharmacy, including bottled fluids, and laundry.

The advantages of this centralisation include economy in provision of staff and equipment as well as reduction of noise in the theatre associated with the maintenance and sterilization of the instruments.

As soon as the operating list for the following day is completed, a copy is delivered to the instrument center, where, in accordance with the list, instruments are packed in sets or ready set-out on trolley tops. Some of these sets may already be stored as standard sterile packs.

Instrument sets are marked with the patient's name, the type of operation, operation number and theatre number. Autoclave proof plastic tags listing contents are attached to sets to facilitate thorough checking and rechecking. The sterile sets are then stored in theatre stores.

If additional instruments or sets for emergency cases are needed the sterile service of the surgical center should be able to deliver them within minutes.

There are recommendations, that in order to protect the sterile service staff, used instruments, after immediate postoperative counting<sup>62)</sup>, should be decontaminated within the confines of the theatre. This should preferably be done in a washer-sterilizer or washer-decontaminator or, if not available, in disinfectant fluid before final cleaning. The instruments may then be returned to the sterile service area either at once or after the operation session is ended.

There is, however, difference of opinion as to the need for sterilization or decontamination of instruments before or during cleaning as there is no available evidence of the extent of this risk<sup>63)</sup>.

Prior to reprocessing, instruments are to be kept stored in the area for non-sterile materials in the sterile service area.

Equipment of the instrument center in the sterile service may include:

- sink with drainer for used and decontaminated instruments

- drainer - preferably in plastic with fairly soft surface — for washed instruments

- highly effective washing machine and rinsing equipment for surgical instruments, work bench and stacking rack

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62) In the question of claims for damages and complaints against doctors in connection with surgical operations in 155 cases in Sweden 11 claims have been based on evidence of residual abdominal compresses, drainage tubes, instruments and such like. (Hellström John: Anmälningar och skadeståndskrav mot läkare i Sverige. 1963, Svenska Läkartidningen 60:1252).

63) Aseptic methods in the operating suite. 1968, The Lancet 1:763-768.



- work benches furnished with racks and drawers for inspection and wrapping of instruments
- two automatic autoclaves sized 41 x 41 x 60 cm<sup>64)</sup> with a sterilization temperature variable between 134-143°C and with prevacuum and postvacuum equivalent to 20 torr
- gas sterilizer for anaesthetic and similar equipment
- storage cupboards for surgical center's non-sterile instruments
- storage cupboard for wrapping materials
- wash basins
- slop sink
- intercom connection to all theatres.

#### Sterilization and maintenance of other items

*A special sterilization and maintenance room for anaesthetic equipment is often preferred instead of relying on the facilities of the instrument center.*

Even though a carefully documented relationship between contaminated equipment and subsequent infection is still needed, the principle is generally honoured that every patient is an individual who must be treated with pathogene-free equipment. This requires that any equipment which comes into contact with the patient's skin or mucous membranes must be cleaned and sterilized after use, stored in a clean store and thereafter handled with particular care.

The fact that no generally accepted scheme exists for decontaminating anaesthetic apparatus is a commentary upon the difficulties involved in adequately processing this type of equipment<sup>65)</sup>.

The size of this cleaning and maintenance room will depend on the number of theatres. Operating table fittings could be decontaminated in the same room.

*Linen sets* for the surgical center are to be sterilized in the central laundry or in the central supply department.

Materials such as *non-disposable syringes, tubes and rubber goods*, should be sterilized in the central supply department of the hospital. This applies even to the stainless steel and plastic equipment. Alternatively, a *special area* within the sterile service should be provided.

A room of about 10 m<sup>2</sup> is needed for decontamination and maintenance to the *stretcher beds*, if used in the surgical center.

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64) if entire trolley tops for instruments, gloves etc. are preferred larger autoclaves are to be installed.

65) Bennet P J, Cope D H P, Thompson R E M: Decontamination of anaesthetic equipment. 1968, *Anaesthesia* 23:674.

## Repair and demonstration shop

With so much depending upon equipment in the theatres and postanaesthetic recovery units, only expert care should be employed for maintenance. The multiplicity and delicacy of modern equipment necessitates a quick repair service.

A *repair shop*, about 15 m<sup>2</sup> in area, with tool cupboards, workbench and special tools will be required.

This room is used by technicians, outside repair men and even demonstrators of new apparatus.

## Facilities for housekeeping and disposing

Routine housekeeping practice by conscientious, intelligent charing staff has to be based on sound bacteriological principles. Until a scientific standard for all hospital housekeeping is clearly established, cleaning will remain to be based largely on speculation.

It is still exceedingly difficult to relate even the most extensive environmental sanitation and elaborate planning features to a change in the post-operative infection rate.

Collection and disposal of water and detergent solutions, storage of unused and used cleaning materials in connection with housekeeping, disposal of soiled linen and pathological preparations are at present usually provided for by a sluice or disposal room common to the whole surgical unit. The transport of unprotected contaminated material to the central disposal room carries certain risks of spreading pathogenic micro-organisms.

It is worth dividing the functions of the traditional sluice room between several rooms: individual theatre disposal room, central soiled linen room, and central cleaners' room.

## Theatre disposal room

Each theatre needs a *disposal room* for the collection and disposal of water and water solutions and storage of used cleaning equipment.

When the operating table is stripped, linen should not touch the floor nor be tossed, thrown or shaken thus allowing organisms to become airborne, but carried at once to the disposal room and there placed in a disposable bag.

Loose linen must not be transported for disposal in chutes. Before disposing the linen it should be checked so that there will be no loss of equipment. Thus also cuts and other injuries to laundry workers are prevented<sup>66)</sup>. In the disposal room used face masks and other disposable articles are also to be stored in disposable bags for the duration of the day's work.

In hospitals with vacuum-driven disposal chutes the disposal room should be connected to the system.

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66) cf also Willingham Jacqueline: Logic of Operating Room Nursing. Springer Publishing Company, Inc. New York 1962, p. 43.

Pathological preparations and excised tissues in closed containers may be temporarily stored in the disposal room. Floor area about 7 m<sup>2</sup>.

#### Housekeepers' room

Besides individual theatre disposal rooms, *housekeepers' rooms* common to the surgical center, for ordinary domestic kind of cleaning, should be available for storing cleaning materials and detergent as well as providing taps and drains. Floor area about 10 m<sup>2</sup>.

Attention should be given to selection of housekeeping personnel and how they enter and leave the surgical center with respect to their equipment and their need to change into appropriate clothing.

#### Unused cleaning equipment for a theatre

Unused cleaning equipment for a theatre is to be placed in the operating theatre store. After cleaning is finished the equipment should be put away in the theatre disposal room.

#### Central soiled linen room

In surgical centers where vacuum-driven chutes are not available, soiled linen and theatre garments collected in the theatre disposal rooms in disposable tightly sealed bags should be removed on the completion of the day's work to a *central soiled linen room* whence, if not collected directly from outside the surgical center, they would be disposed of in a chute conforming to strict hygienic standards. No separate disposal corridor is needed. Floor area about 10 m<sup>2</sup>.

#### Incineration room

In case there is no central *incineration*, a room provided with two incinerators, bench, sink and wash basin, where excised tissues and expendable materials may be disposed of, is recommended.

The capacity of incinerators is to be calculated in accordance with the requirements of the particular surgical center. Relevant fire regulations must be observed. Floor area about 12 m<sup>2</sup>.

## SURFACES AND OPENINGS

### Floors

For theatre, anaesthetic room and equivalent floors, heavy demands must be made on both the mechanical and chemical properties of the flooring material which thus should

- be resistant to scoring and withstand intensive application of water and disinfectants

- have a high resistance to breakdown <sup>67)</sup>

- be homogeneous and not subject to surface cracking <sup>68)</sup>

- be without the tendency, of for example rubber, to absorb physically foreign molecules

- permit either coving against walls or tight jointing to coved skirtings

- be nonslip when wet and with regard to the long working hours in the theatre, kind to the feet

- be sufficiently elastic to recover shape after the removal of pressure, as for example, from operating tables

- not require treatment with preservatives such as wax

- be fireproof

- be coloured so as to conform to the colour scheme of the room, and colourfast.

The requirements for other floor finishes in the surgical center are mostly the same as applied to wards.

Terazzo does not satisfy all the requirements, because of its porosity, hardness, noisiness and tendency to craze, and the time it takes to repair.

Rubber flooring is satisfactory for comfort, but does not as a rule take kindly to heavy loads and will show marks from the operating-table wheels.

Although welded PVC plastic flooring is still under development, it is most likely the floor finish which most nearly satisfies requirements <sup>69)</sup>.

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67) Floors are subjected to shear forces when people walk across them. This action generates particles in relation to the inability of the flooring to resist breakdown. It is possible for 150,000,000 particles, each 1 micron in size, to be generated by wearing away a thickness of 1 micron from an area the size of a postage stamp (Austin Philip R and Timmerman Stewart W: Design and operation of clean rooms. Business New Publishing Company. Detroit, Michigan 1965, p. 145).

68) Porous or uneven surfaces resist chemical decontamination because of the inaccessibility of their bacterial flora (Stedman R L, Kravitz E and Bell H: Studies on the efficiencies of disfectants for use on inanimate objects. 1954, Applied Microbiology 2:322 and 1955, Applied Microbiology 3:71).

Vesley and Michaelsen (1964, Health Laboratory Science 1:107) found no differences in rate of contamination between a sealed and unsealed floor.

69) e.g. Pegulan is a material greatly corresponding to the general demands for floor coverings. Being built up in layers — the top layer consists of poly-vinyl-chloride — and calendered, it is free from air bubbles, very smooth and slipperyproof (slippery angle 49.2°).



In rooms where inflammable anaesthetics are administered or stored risks of explosions caused by electro-static discharge necessitate, as a precaution, the use of conductive floor finishes.

According to the US National Fire Protection Association<sup>70)</sup> the resistance of the conductive floor shall be less than 1,000,000 ohms as measured between two electrodes placed 0.9 m apart at any points on the floor. The resistance of the floor shall be more than 25,000 ohms, as measured between a ground connection and an electrode placed at any point on the floor, and also as measured between two electrodes placed 0.9 m apart at any points on the floor.

Today inflammable anaesthetic agents are no longer in general use. They are used only in very special circumstances<sup>71)</sup>. This fact seems to indicate that the current practice to provide all surgical theatres with conductive flooring and the related expensive equipment is no longer necessary and that only very few of the theatres in a surgical center should be designated for permissible use of such anaesthetics. For the time being a very feasible proportion seems to be one out of five, but never fewer than two in a surgical center.

A conductive floor requires special attention if it is to fulfill its function. Cleaning materials that leave scum or a film on the surface may insulate the floor and counteract its conductivity.

Covered *skirtings* with a minimum radius of 3 cm should be used for all floors.

## Walls

It has been traditionally recommended that wall materials in theatres should be hard, robust, impervious, jointless, nonabsorbent, easily cleaned and decontaminated, and should have relatively nonreflecting surfaces. As yet no material exists which can satisfy all these requirements.

Probably these requirements are held too high, particularly in view of the relatively small hygienic hazard presented by walls. Good quality paint, renewed regularly may be a very acceptable solution. The corners in the theatre must be rounded. Protective guards against damage by the corners of moving equipment are not always effective. Such guards should be made of a very heavy material.

Viewing cabinets, switches, plugs, cupboards and door frames should be flush with the wall surfaces to make cleaning routines easier.

Factory-made wall units with equipment mounted in them so that it can be maintained from outside the theatre may simplify both maintenance and alteration work.

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70) Code for the use of flammable anaesthetics 1965, National Fire Protection Association. Boston 1965, p. 56-27.

71) 9 cases out of 15,000 (Helen M Hill: Dual OR system makes daily conductivity checks practical. 1966, Hospital Administration in Canada 8:9:41-42).

In some industries the vertical walls and partitions in their ultra clean rooms lean into the cleanest areas of the room at an angle of about 3 degrees. There is as yet no proof whatsoever of the bacteriological superiority of such walls over traditional walls.

Some theatres may need screening against outside electrical interference. Electrostatic interferences might distort the sensitive recording equipment monitoring the patient's brain, heart and other body responses.

Shielding systems vary from copper-clad plywood to transparent vinyl sandwich constructions encasing sheets of bronze screen. The latter permit a visual check for breakages in the metal screen and simplify the precise location of holes to be cut in the panels to accommodate pipes, ducts, conduits and equipment.

Permanent radiation screening in an X-ray department should comprise a 2 mm thick sheet of lead or equivalent material in rooms where the working capacity does not exceed 150 kV and radiation is undirected. In operating theatres where X-ray equipment may have the same capacity as that in the X-ray department itself, it is essential to apply the same standards of protection as in the X-ray department.

## Ceilings

The choice of ceiling construction depends on the ventilating and lighting arrangements. Basically the requirements for theatre walls apply to ceilings.

Domed ceilings and hard surfaces have sometimes created unfavourable acoustic conditions in operating theatres.

## Doors

A width of 150 cm for two leaf door openings was proposed by Karman<sup>72)</sup> and the Dutch Bouwcentrum<sup>73)</sup>. This width can still be recommended.

Door openings for staff dressed in sterile surgical garments should have a minimum width of 100 cm.

Theatre and anaesthetic room doors may be provided with glazed opening with blinds. There should be no thresholds.

Theatre doors, preferably sliding doors, should be power operated and controlled by photosensitive cells. Any opening device adapted to the surgical center doors must allow them to be opened manually in case the device fails.

A device that holds the door open must be provided to simplify equipment moving.

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72) Karman Jarbas B: *Cirurgia*. in *Planejamento de hospitais*. Sao Paulo 1954, p. 193.

73) *Dokumentatie Bouwwezen*. Zieken-Huizen. A 5, 1.2.1. Rotterdam 1955, p. 7.

Doors to operating theatres made of wood are readily marked by knocks from operating tables. These and other doors subject to heavy traffic should therefore be protected at least up to a height of 125 cm with rubber, PVC or stainless steel.

The sound insulation properties of the doors themselves could be improved by making kick plates soundabsorbent.

Beck<sup>74)</sup> has recommended doors other than those of the swinging type and found the possibility of air doors to be worthy of investigation.

In noisy workrooms situated in the less clean zones low thresholds of rubber or similar material should be used.

Emergency exits must be clearly labelled.

All doors should be lockable.

The theatres need not have external windows. The factors against windows referred to in the sector on Lighting outweigh those in their favor.

If there are to be windows in the theatre they must be easily accessible for cleaning. If used for ventilation they must be equipped with filter screens and locks requiring special keys as precaution against unintentional disturbance to the interior climate. Windows should also be warmed to counteract condensation and draughts that may discomfort staff and patient.

Blinds should be provided for blackout, privacy and shade.

## Windows

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74) Beck WC: Test Clean Room for Evaluating Contamination. I. The Operating Room Door. 1966, The Guthrie Clinic Bulletin 36:40-47.

## ENVIRONMENTAL SPECIFICATIONS

### Lighting

#### Lighting in the operating theatres

Proper lighting in the operating theatre presents complex problems primarily because of the extremely high levels of shadowless illumination required at the area of incision and because of the need to eliminate the glare and heat often involved. Adequate illumination of the operating field is conducive to precision. Rapid adjustments must be reconciled. The intensity of light in different parts of the theatre ought to be comfortable for all working there. In case of microsurgery these problems are sometimes increased.

A fenestrated operating theatre must often be screened against glare and occasionally for privacy. In several surgical cases it may be darkened entirely. The surgeon working under a spotlight plus general lighting needs no assistance from daylight. Really efficient lighting demands a considerable balance of intensity. The large and unexpected variations in the strength of sunlight make this impossible.

There is little meaning in discussing the psychological aspect of daylight in theatres as it is a matter of taste rather than science and there is no evidence on which one could strictly advise one way or the other. In making the choice, the bactericidal properties of sunlight and the ease of airing during cleaning would probably count for more. However, the surgical center, as a whole, should possess windows on the outside, allowing the staff to be conscious of the transition from daylight to dark.

To obtain optimal visual conditions in the theatre the operating lamp must be considered in combination with complementary lighting and the colour scheme of the room and textiles. The reflection factors of the surfaces of the theatre and those of especially large instruments also play a part.

The intensity of light from the operating lamp should be variable and the general lighting synchronised to vary with it. For the same visual acuity the elderly members of the staff will require more light than their younger colleagues. The latter will, however, not suffer if the level of lighting is designed for the benefit of the former.

There are differences of opinion concerning the suitable intensity of light in the operating field. Just as too little light will handicap vision, so will too much overtax it. The general tendency is, however, clearly towards greater and greater intensities.

The development of French recommendations can be cited as examples: 1944 — min. 1,500 lux<sup>1)</sup>; 1953 — 3,000 lux; 1955 — min. 15-20,000 lux; as well as the Swedish Society of Illuminating Engineers who suggested in 1953: 300 lux for general lighting and 2,000-8,000 lux for the operating lamp, and in 1962: 1,000 and 30,000 lux respectively.

In the USA an intensity of 100,000 lux has been considered desirable for certain neuro-surgical operations. By comparison, the intensity of sunlight on a clear summer days is

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1) 1 lux = 1 lumen/m<sup>2</sup> = 1/10,764 footcandle



in the region of more than 100,000 lux, in the shade 10,000 lux, and immediately inside a window on the shade side of a building about 200 lux.

The differences between past and present recommendations might be taken also as a guide to what has been technically possible during the period covered.

Visual acuity increases rapidly at first with increased light intensity, but more slowly with subsequent increases until a point is reached where improvement in acuity ceases whatever the intensity. There is then nothing to be gained from a higher intensity except the negative gain of glare.

It would be realistic therefore to require an all-round intensity of no more than 40,000 lux from an operating lamp placed one metre above the working plane, giving an intensity of 8,000 lux at the bottom of an incision about 13 cm deep and 5 cm wide.

What a surgeon is used to will tend to determine his judgement of the colour composition of theatre lighting. This explains the disparity between two common American makes of operating lamp which is 3,800°K and 6,500°K respectively. For the majority of clinical purposes a lamp with a correlated colour temperature in the region of 4,000°K is desirable, and it should imitate as closely as possible a full radiator at this colour temperature in both chromaticity and distribution of spectral power <sup>2)</sup>.

The colour characteristics of surgical lighting are not critical for the surgeon, as he can accustom himself to almost any lighting provided that it is sufficiently bright. Coloured light sources may be useful in differentiating tissues by intensifying contrast between them.

The spectral composition of light is much more important for the verification of the patient's skin colour which may warn the anaesthetist of poor circulation and lack of oxygen. There is a serious situation if the patient's blood or colour appears blue. The anaesthetist will in such a situation immediately increase the concentration of oxygen in the anaesthetic mixture with the result that the patient may awaken during the surgical procedure. Probably in the future exact measurements will be possible of physical characteristics which now are susceptible only to the anaesthetist's subjective judgement.

The degree of distraction is a function of the size and brightness of the working area and also of the brightness of the surroundings. As a general condition for good working illumination it has been thought desirable that the general field should comprise not less than one third of the intensity of the special field. Within the special field a disparity not greater than 10:1 should be permitted between the centre and the periphery of the visual field.

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2) Spectral Requirements of Light Sources for Clinical Purposes. Medical Research Council Memorandum No. 43. London 1965, p. 27.

Experiments at the British Building Research Station<sup>3)</sup> show that a maximum of visual comfort obtains at a ratio of 100:30:3; meaning the progressive reduction in intensity from the operating field, through the immediate environment to the rest of the theatre. Between the lamp and its background the ratio of brightness should not exceed 15:1.

The general lighting plus complementary lighting, provided that the different surface reflections do not vary too much, should attain a minimum of 1,000 lux where the working intensity is 10,000 lux. Small fluctuations in the intensity of light, with irregular intervals are desirable.

The spectral composition of the general lighting in the theatre should be the same as that in the operating field.

Changing from one form of light to another interferes with colour appreciation, and the interpretation of the colour of blood, lips, fingers and ears may become exceedingly difficult.

In dark surroundings the attention is held more readily. If in an operating theatre general lighting of a high intensity is to be provided, the decision when to use it and at what intensity should rest with the surgeon. He alone can decide when he wishes to work under the visually most comfortable conditions, and when to concentrate his attention. The surgeon should use this control with due respect to the needs of the anaesthetist and the assistants.

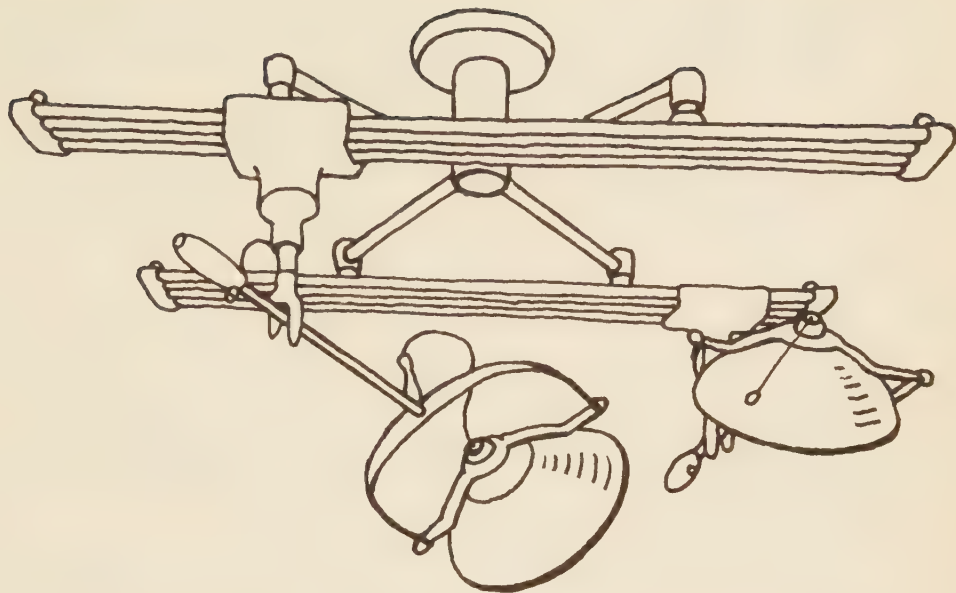
The following will be required of an *operating lamp*:

- that both the field and the intensity of light be sufficient and variable (40,000 lux one meter above the working plane, giving an intensity of 8,000 lux at the bottom of an incision 13 cm deep and 5 cm wide)
- that a proper balance be struck between disturbing shadow and that necessary to the surgeon for the judgement of contour and distance
- that it be provided with quick, accurate and foolproof control
- that the colour spectrum be about 4,000°K
- that heat radiation be to all intents eliminated <sup>4)</sup>
- that a non-splintering glass should be used
- that the lamp be easily cleaned
- that the light source of the fixture be suitably protected against physical damage
- that the electrical circuit for the operating lamp should function even during power failures
- that the lamp fitting be of simple design and easily accessible for replacement, repair and maintenance
- that the lamp be sufficient to illuminate two operating fields simultaneously

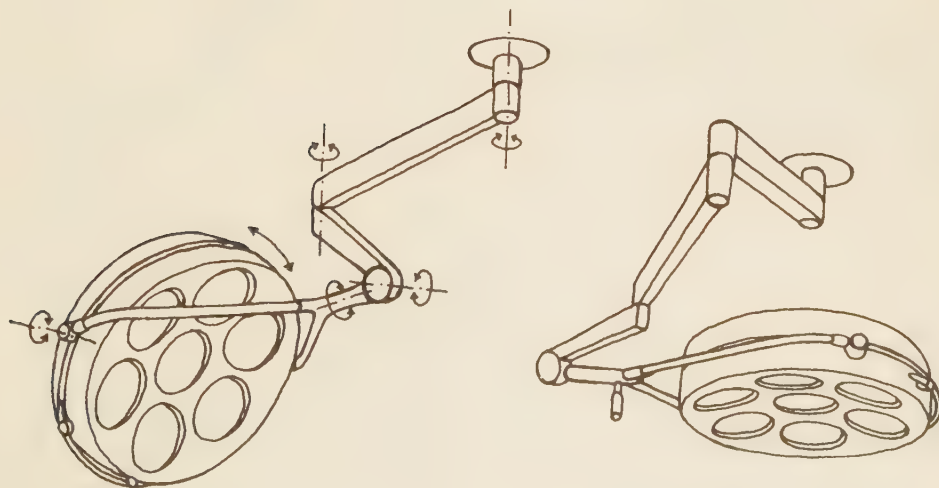
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3) Hopkinson R G: The Lighting of operating theatres. in Operating Theatres and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 182.

4) Burns are shown to occur if the skin temperature is raised above a critical level of 44°C according to Robin Fraser (Radiant heat burns and operating theatre lamps: a study of the heat required to cause tissue necrosis. 1967, The Medical Journal of Australia 54:1:1199-1202).



*TRACK TYPE SURGICAL LIGHTS. EACH LIGHT WITH A SINGLE LAMP SET IN A REFLECTOR OF ABOUT 60 CM DIAMETER RUNNING ON DUAL TRACKS.*



*FIXED OPERATING THEATRE LIGHT-FITTINGS USING SEVERAL LOW VOLT-AGE TUNGSTEN BULBS (HANAU-LUX).*

that the relevant electrical security regulations be followed if possible, the lamp should incorporate a mirror for the anaesthetist to view the surgical performance.

The Xenon discharge lamp has the necessary combination of very high brightness with a spectral composition very little removed from natural light.

Beaming light by means of a glass fibre tube in an operating lamp makes it possible to eliminate infrared radiation completely. Only visible light strikes the wound.

Fluorescent sources may be used for operating table lights when surgical work is confined to larger fields such as skin grafting. Experiments with two large banks of cool white fluorescent lights show <sup>5)</sup> that visual images are flat as no shadows are cast to provide modeling that causes blood vessels and other structures to stand out in the depth of a wound. The customary rendition is altered making purples, reds and blues purplish and tissues appear cyanotic.

Another form of theatre lighting comprises a series of spotlights built into walls and ceilings which can be switched on from control panels either individually or collectively (e.g. the systems developed by Nelson and Blin). Still another comprises movable lamps suspended or on rails above a transparent theatre ceiling.

For some time to come most operating lamps will probably be composed of incandescent filament lamps with their advantages of high brightness combined with small size. Experience shows that suspended incandescent filament operating lamps are generally most accepted — basically because they are by far the least expensive. A disadvantage is that the maintenance can be carried out only when the theatre is not in use.

#### Lighting in ancillary rooms

For a patient in hospital far away from a familiar environment the visual comfort is of paramount importance in supporting his self-confidence. The main causes for complaint from patients seem to be glare from light sources and reflecting surfaces.

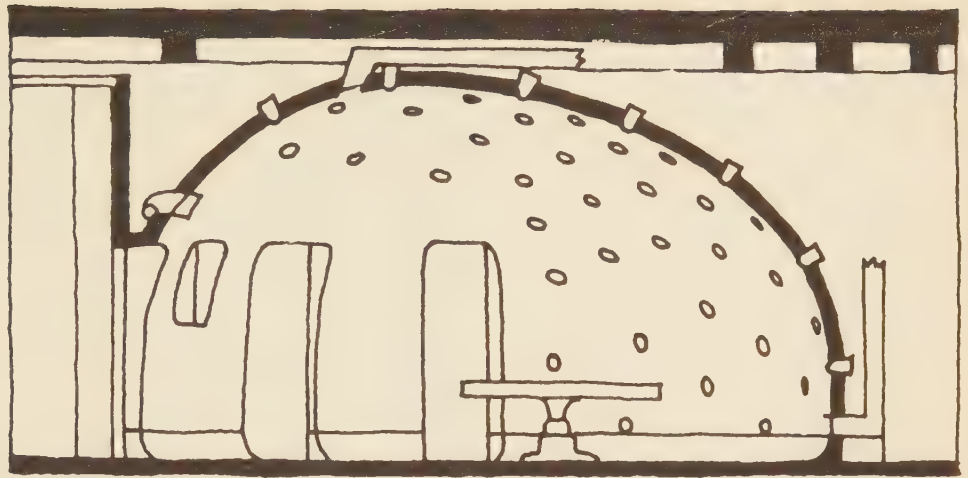
So the general lighting should be free from glare and luminaires for direct lighting should have the greatest possible reflective area and be constructed to minimize the contrast between reflecting surface and ceiling. Lighting intensities must be determined in relation to the tone of wall and ceiling colours.

During preoperative procedures in the holding area and anaesthetic rooms the patient's regard tends to be fixed on the ceiling; special attention should therefore be directed towards reducing the contrast between light fittings

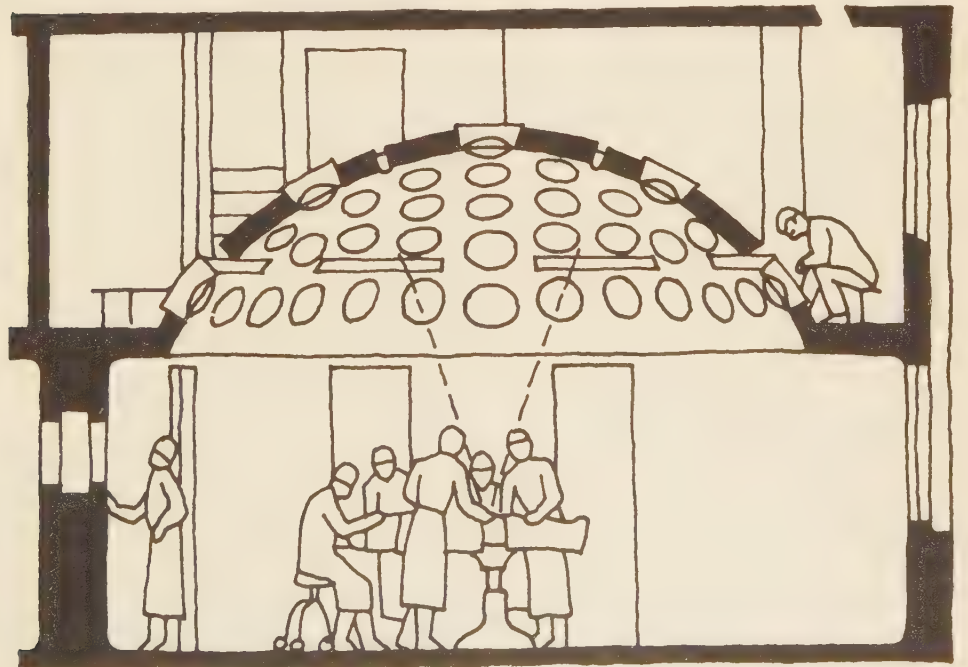
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5) Heimburger Robert F, Kimball Paul and Schnitker Norman F: Experimental system affords better surgical lighting. 1968, Hospitals 42:15:18.





*Paul Nelsons design includes about seventy small projectors embedded in the walls and ceiling of an egg-shaped theatre. The table itself must be moved to alter the position of the illuminated field on the patient's body.*



*Jean Blins theatre has a domed ceiling into which are built multiple fixed projectors which can be switched on in groups, according to the direction from which light is required. The operating table may need to be moved to place the patient correctly in relation to the illuminated field.*

and the ceiling. Indirect lighting, complemented with some direct lighting to attain a total intensity of 300 lux, should be achieved.

A light source in the anaesthetic room must provide a high intensity locally, but should at the same time be variable in intensity and towards red in colour, not least for the sake of child patients.

Also in postanaesthetic rooms the anaesthetist places constant reliance on his assessment of the patient's colour. The importance of this matter cannot be overemphasized.

In order to avoid difficulties in visual adaptation the intensity of general lighting in the scrub-up room should be about the same as that in the operating theatre.

As a check on the standards of general hygiene in the surgical center, the value of good general lighting cannot be too much stressed.

## Colour

Generally with high levels of illumination, luminous and warm colours (pink, orange, yellow) in the surroundings, the body tends to direct its attention outward, increasing its activation in general. With softer surroundings, lower brightness and cooler hues (turquoise, green, blue, grey) there is less distraction and good inward orientation is furthered <sup>6)</sup>.

There is a risk of vision disability when looking into a wound by contrast with the towels and drapes surrounding it. Dark green has been usual to minimize contrast glare. Canada Green has been particularly recommended <sup>7)</sup>, although it could be felt that the colour of the drapes should be somewhere between that of the skin and the incision or wound so that the retina need not make extra adjustments when the eye moves from the linens to the operative area. Rather dark green gives minimal interference with the true appearance of flesh, fat and organs on closed circuit television, both colour and black and white.

Grey-green, grey-blue, neutral beige, yellow and pale yellow, all with reflection factors of 25-35 per cent, have equally been recommended, usually in combination with a white ceiling.

Most persons, however, have strong likes and dislikes regarding colour, so quite naturally different groups have arrived at different conclusions on suitable colour schemes for operating theatres.

The operating theatre at the New York Polyclinic Medical School may well be referred to as an example of a most elaborate colour scheme. The ceiling is pale yellow shading into the walls into a deeper yellow which continues

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6) cf also Birren Faber: *Color it color*. 1967, *Progressive Architecture* 48:9:129-133.

7) Fair Jim: Standardization program for O.R. drapes covers two central laundries serving 20 hospitals. 1968, *Hospital Administration in Canada* 10:5:42-48.

down the upper third of the walls, which are otherwise green and finished with a blue skirting near the floor. The floor is green and the operating lamp is provided with a yellow filter, the patient's head rests on a yellow sheet, and his lower limbs are also clothed in yellow. The rest of his drapes are green.

A German group composed of surgeons, architects and colour experts<sup>8)</sup> recommended grey-green walls, grey floor and bright yellow ceiling for the operating theatre.

The Nuffield report<sup>9)</sup> states that white walls cause glare and recommends pale green with a reflection factor between 42-56 per cent.

The British Ministry of Health<sup>10)</sup> has recommended green, blue, and grey with reflection factors of 50 per cent.

The Dutch Bouwcentrum<sup>11)</sup> suggests that walls be in a neutral colour but not green or blue, with ceiling in the same colour as the walls but lighter.

Birren<sup>12)</sup> suggests for the surgery and adjacent rooms light blue-green with medium blue-green in the theatre itself, ceilings in both areas being white.

Velikoretsky<sup>13)</sup> considers greenish, bluish, grey or blue the most appropriate.

White<sup>14)</sup> has found that preferred colours are grey, beige, pale yellow and pale green.

For lack of conclusive scientific information on the subject it would be wisest for the present to adopt neutral colours, particularly in areas where colour identification is important.

The colour scheme in the anaesthetic room may be the same as that for the theatre, if not softer and warmer. It is important that the colour of the anaesthetic and postanesthetic rooms be chosen with regard to the fact that reflections on the patient's face can obstruct the anaesthetist's judgement of the patient's condition through observation of his complexion. The staff entrusted to care for patients is required to observe the colour of the patient's skin, whether pink, bluish, pale or ashen grey. Any change could indicate impending respiratory obstruction, sudden haemorrhage or surgical shock.

The colour scheme in the scrub-up room has shown trends towards the use of yellowish or red shades.

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8) Bansels H G: Farbenpsychologie im Kulmbacher Krankenhaus. 1960, Krankenhaus Umschau 29:527-529.

9) Nuffield Provincial Hospital Trust: Studies in the Functions and Design of Hospital. Oxford University Press. London 1955, p. 65.

10) The Ministry of Health, England and the Department of Health for Scotland: Operating Theatre Suites. London 1957, p. 26.

11) Building Bulletins: Hospitals. A5 1.2.1. Bouwcentrum. Rotterdam 1955.

12) Birren Faber: Color for Interiors. Whitney Library of Design, New York, no publishing year, p. 152.

13) Velikoretsky A: Text-book of Surgery. Foreign Languages Publishing House. Moscow (1963), p. 43.

14) White T: Architectural Research Project on Finishes and Fittings in Operating Suites. Stencil. Newcastle 1965, p. 12.

In waiting and holding areas blue or blue-green shades should be used, as they have been considered to be calming.

## Acoustics

Work in a surgical center depends on ease of communication, and this applies to corridors and anaesthetic rooms as well as to theatres. Informative sounds from monitoring equipment, alarm signals and the public address system should be clearly audible.

The deleterious effects of noise may impinge on the verbal exchange of information, the processes of anaesthesia or may cause psychological disturbance. It is not possible to get used to disturbing background noises. They always influence the bloodpressure factors.

Disturbance to conversation may be trying especially in theatres where faces are masked and suction pumps or compressors are at work. It may be difficult to understand orders especially for those at a distance from the surgeon. Though more difficult to define, the psychological disturbance of sudden noises would certainly be trying for operating staff.

External sources of noise include motor traffic, aircraft, building construction and similar noisy activities. The definition embraces also noise sources within the building such as mechanical installations: lifts, water and drain pipes, ventilation ducts and fans, and installations serving other purposes within the building but outside the surgical center.

Principal internal sources of noise are ventilating installations — air moving through the components of the system and noise generated by the mechanical parts of the plant — together with transient sounds such as footsteps, conversation, staff paging, activities in rooms with stainless surfaces, tinkling of glasses, the sluicing of water and the slamming of doors.

The need for silence during the induction of anaesthesia is emphasized by warning signals. It is important that the anaesthetic room be well insulated against external noise and against other noise of irregular occurrence.

Measured sound from fans should not exceed 35 decibels in anaesthetic rooms and 40 decibels in operating theatres<sup>15)</sup>. The reverberation time in theatres should be reduced to below one second. In anaesthetic rooms and corridors sound absorption should be adequately provided for.

The maximum level here proposed requires the provision of insulation against airborne sound between rooms, especially between corridors and anaesthetic rooms, where sound reductions of 25–30 decibels should obtain with a reduction of approximately 20 decibels between the corridor and the operating theatre<sup>15)</sup>.

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15) personal communication: Tor Kihlman TechD and S Nordlund MD; Gothenburg.



Some benefits accrue from the attention given to such details as glazed panels in doors which may save unnecessary opening, and signals to warn against disturbance during the induction of anaesthesia. Similarly, silent running apparatus — stretcher wheels, operating tables etc — should be chosen. All sanitary installations, including sinks, should be constructed and mounted so as to minimize noise.

The choice of floor, wall and window construction will be influenced by the noise sources involved.

Both the construction of the floor and the choice of the material of shoes for the staff can contribute to a reduction of impact noise.

In the operating theatre the boredom and fatigue arising after long periods of close work may cause a slackening of concentration, and conversation may become general, thus greatly increasing the number of airborne bacteria. Background music might be helpful in mitigating the boredom.

When hyperbaric chambers are used the noise of the compressors, blowers and air conditioner is often found trying. Piped-in music helps to distract the attention from less pleasant noise, and to mask it to some extent.

## Climate

### Temperature

The character of the thermal environment of the theatre and anaesthetic room is determined by the factors of protecting the patient's physical resources and ensuring proper working conditions for the operating staff to which Ellis<sup>17)</sup> has supplemented the need to reduce the mobilization and dispersal of pathogenic micro-organisms from the skin of the staff and patient by preventing excessive perspiration.

Little is known about optimum conditions for maintaining normal body temperature during anaesthesia and the immediate postoperative period. Although the patient cannot be consulted, the mean skin temperature can be recorded and variations closely correlated with his preferences when conscious. Celander's observation<sup>18)</sup> shows that air temperature inside swaddling clothes may be at 35° C when room temperature is only 25° C. Much work remains to be done on how different temperature levels influence the patient under his drapes.

In case of operative shocks, temperature control requires that the patient be comfortably warm. Excessive external heat tends to produce undesirable vasodilation with a further decrease of the circulating blood volume<sup>19)</sup>.

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17) Ellis F P: Better operating conditions. 1965, The Lancet 2:345.

18) Scopes John W: Metabolic rate and temperature control in the human body. 1966, British Medical Bulletin 22:1:88.

19) Pollock Joseph H: A survey of surgical shock. Charles C Thomas Publisher. Springfield. Illinois 1966, p. 14.

The fluid losses through sweating during a prolonged operation can be considerable in an adult <sup>20)</sup>.

Walker and Derrick <sup>21)</sup> have studied patients during a major thoracic surgery and found that temperature has to be controlled to protect the patient's heart muscle, which is irritated by even minor changes in temperature.

Temperature control of the infant is an essential component of paediatric surgery. It has been pointed out <sup>22)</sup> that the responses of young children under general anaesthesia in particular are poikilothermic in character, because shivering is abolished and there is peripheral vasodilation. The effect is greater than in the adult because of the infant's larger body surface in comparison to its total bulk.

Low temperature, particularly for patients less than one year old, as well as high temperatures, may be gravely injurious. The hypothermia produced in the air-conditioned operating room in the absence of any heat source has been associated with increased morbidity and mortality <sup>23)</sup>.

A temperature between 32 and 34° C has been accepted as the neutral air temperature for the newborn infant as oxygen consumption is then minimal <sup>24)</sup>. However, there are wide variations in cold resistance among neonates.

The medical requirements for *cooling* the air in operation theatres have not yet been officially stated.

When refrigeration and air-conditioning are available, there is a considerable risk of over-cooling the patient, if the control mechanisms are not in good order. When air-conditioning and refrigeration are not available, there is a risk of over-heating him, if the weather suddenly turns warm and one does not take reasonable precautions. This is a situation which is potentially more hazardous than any encountered in hot industries as the patient is usually unconscious and may be a poikilotherm as well.

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20) cf also Varco Richard L: Principles of Preoperative and Postoperative Care. in Christopher's Textbook of Surgery. ed by Lloyd Davis. W B Saunders Company. Philadelphia and London 1964, p. 94 — 95.

21) Walker Joe A and Derrick John R: Management of the Patient Before and During Major Thoracic Surgery. 1966, The American Surgeon 32:457.

22) Ellis F P: The Control of Operating Suite Temperature. 1963, British Journal of Industrial Medicine 20:286.

Rashad Karim F and Benson Donald W: Study role of humidity in preserving normothermia during anaesthesia. 1967, Hospital Topics 45:5:83 — 84.

23) Farman J V: Heat losses in infants undergoing surgery in air-conditioned theatres. 1962, British Journal of Anaesthesia 34:543—556.

24) Silverman William A and Sinclair John C: Temperature Regulation in the Newborn Infant. 1966, The New England Journal of Medicine 274:147.

What is best for the patient so far remains undefined. A more precise definition of the thermal requirement of the unconscious patient is needed.

Views and opinions on what constitutes a comfortable working temperature for the staff in a theatre have changed during the last few decades effecting a reduction in what had been the generally accepted standard of 28 – 30°C to 18 – 25°C.

Thermal comfort requirements vary in different parts of the world and in different parts of any particular country, with changes in season, or with different levels of activity. The range of air temperature at which the metabolic rate is lowest, is for man 24 – 31°C <sup>25)</sup>.

Although humans vary considerably in their comfort levels, the healthy human body can, within limits, adjust its heat production to suit thermal conditions.

When making assessment of room temperatures, consideration should be taken also of draughts caused by air circulation and of radiant heat which is influenced by the close grouping of persons in the theatre. The temperature in the theatre is usually registered on a wall thermometer which does not give an accurate indication of the condition prevailing at the operating table.

The staff and nervous tension should ideally be submerged in dry and cool air. From the studies of Lidwell <sup>26)</sup> it seems to be clear, that conditions which may satisfy the surgeon will often lead to the anaesthetist complaining of cold. Whether it is possible to produce for all parties a comfortable working environment without changes for example in staff clothing is doubtful and even with such changes the comfortable working environment may remain unattained.

Admitting that experiments have shown that the thermal environment has an effect on the efficiency and accuracy of procedures carried out by staff, the extent of the effect of the thermal environment on the efficiency of surgical teams is still to be determined. It has already been recognized that a fixed indoor temperature does not assume comfort.

No background heating is generally needed to internal theatres having no external walls since the air volume in connection with the suggested number of air changes will ensure that satisfactory conditions will exist within 20 minutes of switching on the ventilating plant. If used, floor heating causes undesirable rising air streams and too quick drying of the theatre floor. To reduce airborne dust the floor should remain damp for as long as possible after washing.

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25) Environmental Biology, ed by Philip L. Altman and Dorothy S. Dittmer. Federation of American Societies for Experimental Biology. Bethesda, Maryland 1966, p. 1.

26) Lidwell O. M.: The ventilation of operating suites. The Institution of Heating and Ventilating Engineers. Symposium 12th January 1966. London 1966, p. 88.

Good heating should be accomplished without appreciable air movement and with heating surfaces maintaining a temperature below the dust carbonization point. This can be achieved by means of large surfaces maintained at low temperatures.

Large surfaces such as ceilings and walls are suitable also for radiant cooling. E.g. *Stramax* (Zurich, Switzerland) Heating and Cooling System establishes a proper environmental conditioning by a pipe system below the structural ceiling, carrying either hot or cold water, which transmits, via a suitable interposing conductor in direct contact, heating or cooling to a plaster layer. This in turn absorbs or emits radiation with a heating or cooling effect.

Boyar, Brown and Shaffer <sup>27)</sup> have shown that the bacterial count in a room with radiant heating in the ceiling is substantially lower than in a room heated by convectors.

Another suitable alternative is warm-air heating.

Radiators are a nuisance to clean, and therefore have a counter-aseptic regime appearance; they look as if cleanliness has not been bothered about very much.

## Humidity

No documented statistics seem to be available on the general value of humidity to adults. However, humidity in the operating theatre is believed to contribute to the prevention of dehydration of exposed tissues. For newborn and premature infants 55 to 65 per cent relative humidity is desirable <sup>28)</sup>.

Humidity has also been considered to hinder the accumulation of electrostatic charges on persons and objects and thus eliminate the risk of explosion when inflammable anaesthetics are used. The use of anaesthetic gases or vapours which themselves (cyclopropane) or when combined with oxygen or nitrous oxide, form an explosive mixture, evidently gives rise to grave hazards for both patients and staff. The reported frequency of mortality from this cause in the USA <sup>29)</sup> is one per 300,000, in Canada <sup>30)</sup> one per 80,000 – 100,000 and in Sweden <sup>31)</sup> one per 700,000 operations.

An explosion in the operating theatre, although statistically very infrequent has nonetheless a great psychological impact both upon the theatre staff

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27) Boyar R E, Brown W K and Shaffer H C: Radiant ceilings tested for bacteria count. 1966, *Modern Hospital* 106:6:160–162.

28) Hospital care of newborn infants. American Academy of Pediatrics. Evanston, Ill. 1960, p. 83.

29) Walter Carl W: Anaesthetic explosions: a continuing threat. 1965, *Hospital Topics* 43:2:95–102.

30) Sereda P S: Special facilities can reduce operating theatre hazards. 1962, *Canadian Hospital* 39:6:62–64.

31) Sjöberg Bengt: Explosionsfarliga narkosgaser. 1965, *Läkartidningen* 62:35:2749.



and the general public. To minimize the risk of explosions in the operating centre it has been requested that a standard of relative humidity be fixed for the anaesthetic locations.

The recommended standards have varied between a minimum of 50 per cent <sup>32)</sup> to a percentage of 60 to 65 <sup>33)</sup>.

Harder <sup>34)</sup> has stated that for the prevention of electrostatic charging the relative humidity should be maintained at 70 per cent. This degree of humidity is however unbearable for the patient and staff.

A British Ministry of Health Working Party on Anaesthetic Explosions <sup>35)</sup> has pointed out that it would be dangerous to fix on an ideal standard of relative humidity for it might give a false sense of security. Electrostatic sparks can still be produced when relative humidity is in the sixties and seventies.

It should be remembered that no device can be an adequate substitute for the constant alertness of the anaesthetist and his awareness of the hazards associated with the use of explosive agents.

When the use of inflammable anaesthetics is abandoned — already a dominating situation — it is not necessary to maintain a relative humidity of 50 per cent or greater in the whole surgical center as it is used solely as a means for the prevention of electrostatic accumulation relative to the ignition of inflammable anaesthetics. A reduction of humidity in general conditions to about 40 to 45 per cent would be found more acceptable. When very young children are involved the humidity should be correspondingly increased.

In the theatre it is best for the patient that the surgeon be comfortable and alert.

Where full air conditioning exists, a relative humidity of over 70 per cent has been regarded as quite comfortable provided the temperature is not

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32) cf also Karman Jarbas B: *Cirurgia. in Planejamento de hospitais*. Sao Paulo 1954, p. 197.

Gaulin Richard P: *The Effect of Hospital Infections on Air Conditioning Design*. 1962, *The Hospital Engineer* 16:289–294.

Hughes H G, Starkey D H and Klassen J: *Conditionnement de l'air des theatres operatoires par rapport a la lutte contre les infections*. 1963, *Hospital d'Aujourd'hui* 9:1:16–22.

Canadian Standards Association: *Code for the use of flammable anaesthetics (Safe practice for operating rooms)*. Bulletin Z 32. Ottawa 1963.

*Code for the use of flammable anaesthetics* 1965. National Fire Protection Association. Boston 1965, p. 56–12.

33) Schmitt Walter: *Allgemeine Chirurgie*. Johann Ambrosius Barth. Leipzig 1966, p. 101.

34) Harder Hans Joachim: *Technische Sicherheitsprobleme im Operationstrakt*. Springer-Verlag. Berlin, Heidelberg, New York 1965, p. 66.

35) *Report of a Working Party on Anaesthetic Explosions*. Ministry of Health. Her Majesty's Stationary Office. London 1956. Reprinted 1961, p. 6.

allowed to rise above 20 – 21°C<sup>36)</sup>. Lower levels of humidity would, however, promote greater comfort. In the United Kingdom a temperature of 18 to 21°C and a relative humidity of slightly more than 50 per cent are preferred. In East Europe the most liked winter temperature is 18 to 20°C and in summer 20 – 22°C with a relative humidity of 55 per cent. In South Africa a temperature of 18 to 24°C and a relative humidity of 50 to 60 per cent have been found well tolerable.

Studies and research carried out by the American Society of Heating, Air Conditioning and Refrigerating Engineers indicate that an effective temperature of 22°C (corresponding to an air temperature of 24 – 25°C, the relative humidity being 37 – 60 per cent and with a slow circulation of air) should be the optimum for the surgeon.

Dawson and Lynn<sup>37)</sup> recommend for infants in the operating theatre a temperature of 22°C and a relative humidity of 50 per cent.

The air temperature of 21 to 24°C with 50 to 60 per cent relative humidity has provided in the United States a compromise between the supposed requirements of the patient and those of the surgeon.

It seems that in surgical centers in Scandinavia and countries with similar climate, in the theatres a range in temperatures from 18°C to 30°C should be provided with the relative humidity varying between 40 to 60 per cent in accordance with the particular needs of the actual operation. In minor centers the range in temperatures could be limited from 18°C to 25°C. These climatic values require the installation of full air-conditioning equipment.

Even the provision of a highly favourable set of thermal conditions is unlikely ever to guarantee comfort for everyone. Fortunately, there is some tolerance in the air temperature within which any individual doing no more than light work will be reasonably comfortable, and an even wider permissible tolerance in relative humidity.

#### Frequency of air changes

To maintain an oxygen content in the air adequate for ten persons in the theatre, a volume of 14 to 28 m<sup>3</sup> of air will be required per hour<sup>38)</sup> with the implication that one tenth of the theatre air volume would be replaced every hour. For the sake of comfort a rise of temperature is to be avoided and a light increase in the frequency of air exchanges is therefore necessary. To control odour six changes per hour are required.

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36) Burns T H S: Fires and Explosions. in A Practice of Anaesthesia. ed by W D Wylie and H C Churchill-Davidson. Lloyd-Luke. London 1966, p. 448.

37) Dawson Brian and Lynn Hugh B: The Pediatric Patient in the Operating Room. 1965, The Surgical Clinics of North America 45:955.

38) Edwards Ronald in Operating Theatres and Ancillary Rooms. ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 39.

For the removal of bacteria from the air the number of changes has to be considerably increased. Eight air changes an hour — which has been recommended — do not remove all bacteria from the air; indeed, the efficiency compares very closely to the rate of bacterial disappearance observed when the air is not circulated at all<sup>39)</sup>.

The removal of airborne organisms, whether by ventilation, disinfection or both, follows an exponential die-away curve. Threshold sanitary ventilation can be provided for ordinary occupied places by about sixty air changes an hour thus average surgical teams require theoretically at least sixty air changes — which is impracticable — and teams with poor hygienic technique about three hundred.

As earlier indicated, the role of airborne bacteria in connection with post surgical infections is not conclusively established. The rise of air change frequency for this particular aspect should therefore be kept modest. It must be stressed once again, concerning the level of bacterial contamination in the theatre that it is of greater importance to deny subsidiary staff entrance to the theatre than to increase the number of air changes.

Conventionally 1/5 of threshold sanitary ventilation, corresponding to approximately 12 changes per hour, is provided.

Cairns<sup>40)</sup> demanded that operating theatre ventilation has to be planned in relation to that for the rest of the center, so that the movement of air is always towards less clean areas. Airborne contamination from the wards to the surgical center may be serious, particularly when the center is at the top of a tall building, where the stack effect causes upward air currents through stairways and lift shafts.

It is, however, uncertain what rate of air flow is required to prevent the flow of air to the operating room from those adjoining<sup>41)</sup>. It is generally believed that to provide reliable positive pressure, a minimum supply of 10 changes of air an hour is required. If more than about one third of this air is taken away by an extraction fan it is unlikely that satisfactory positive pressure will be maintained<sup>42)</sup>.

Planned directions of air-flow cannot be maintained continuously as open doors and the movement of people to and fro cause eddies and even reversals of flow that are neither easily predicted nor easily prevented.

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39) Cole William R, Bernard Harvey R, Gravens Daniel L: Control of Airborne Bacteria in Operating Rooms. 1965, Hospitals 39:6:79-84.

40) Cairns Hugh: Bacterial Infection During Intracranial Operations. 1939, The Lancet 1:1198.

41) cf also Ma Wm Y L: Air Conditioning Design for Hospital Operating Rooms. 1965, The Hospital Engineer 19:263.

42) Shooter R A and Williams R E O: Prevention of infection in operating theatres. 1961, Journal of Clinical Pathology 14:1:45-48.

Unless very high ventilation rates are achieved an air conditioning system cannot offer a guarantee against the considerable theoretical risk of airborne infection. *The minimum rate of 12 changes an hour should be sufficient for comfort as well as to ensure pressurization in the theatre and to maintain control of airborne micro-organisms if an average surgical team is involved*, as there is no proof that a higher rate of e. g. 20 changes gives a better result.

This recommendation is not applicable in connection with operations which require sterility as the prime condition for success. As examples of such operations transplantation of heart, some neurosurgical and thoracosurgical operations could be mentioned.

#### Operating theatre ventilation

It is immaterial whether the ventilation system provides actual fresh air or air that has been made the sanitary equivalent of fresh air by the removal or destruction of pathogenic particles.

It has been a common practice for an operating theatre to be ventilated with 100 per cent outside air. Recently and mainly in the USA, systems are designed to provide from 20 to 80 per cent recirculation.

Bernard, Cole and Claywell<sup>43)</sup> report on a test of recirculated air in the surgical suite. During a four-month period, bacterial air contamination was as well controlled in an operating room where 80 per cent of the air was recirculated through a dry filter as it was in a second operating room where the air was provided through a large electrostatic filter and discarded after one passage. During the test, the average number of bacterial particles remained five per cubic foot in both rooms, and a ratio of one coagulase-positive staphylococcus-bearing particles to 300 of all other viable bacterial particles was maintained. Analysis shows a 65 per cent reduction in cost for the 80 per cent recirculated air system as compared with the 100 per cent outside air system.

It should be observed that recirculation greatly increases demands on the filtration system.

The three *main patterns of air distribution* in the operating theatres are: mixing or turbulent, downward displacement piston, and laminar flow or air curtaining. To make a choice among these systems is difficult. On the other hand, as Ma<sup>44)</sup> has indicated, the choice affects only the final 10 per cent of the performance of the theatre airconditioning system and thus has relatively little importance.

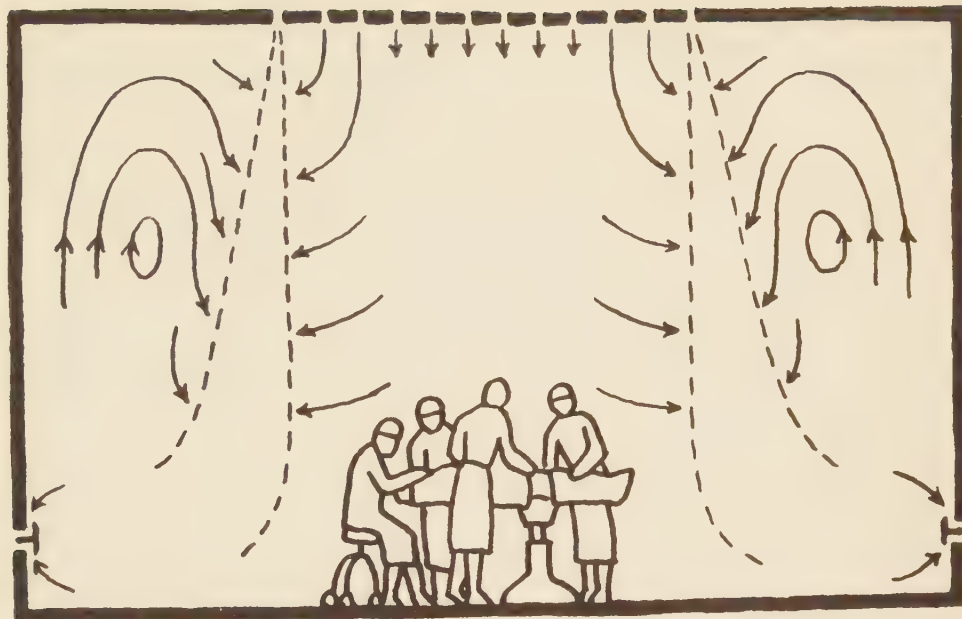
The mixing method employs turbulent mixing of incoming air with the air already in the theatre. By this means the contaminated air is diluted and exhausted through outlets.

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43) Bernard Harvey R, Cole William R and Claywell James C in 1961, Hospital 35:21:46-50.

44) Ma Wm Y L: Air Conditioning Design for Hospital Operating Rooms. 1965, The Hospital Engineer 19:262.





*CEILING-TO-FLOOR DOWN-FLOW AIR CURTAINING IN A SURGICAL THEATRE*

In downward displacement the incoming air is taken in at the top of the theatre in order to displace the air at lower levels.

Lidwell, Richards and Polakoff <sup>45)</sup> have investigated low velocity turbulent, moderate velocity turbulent and downward displacement piston systems and found no evidence to suggest that any one of the systems was significantly superior to the others in protecting a surgical wound from contamination with airborne bacteria in the surgical theatre.

Laminar air flow is a system combining high efficiency air filtration with a directed movement of air establishing air curtains to carry particles away from the critical area.

In the air curtaining method, the air is to be introduced in the form of a large-surfaced buffer moving at almost constant speed in a single sweep across the length of the area. Air is also to be projected in such a way that it provides a barrier, which should reduce the risk of contamination. An essential prerequisite of this single sweep technique is that there should be an adequate area for the return air plenum.

<sup>45)</sup> Lidwell O M, Richards I D G and Polakoff S: Comparison of three ventilating systems in an operating room. 1967, *Journal of Hygiene* 65:203.

Hughes, Starkey and Klassen<sup>46)</sup> direct an air stream from wall grilles to pass from the feet of the patient towards his head. In this way fresh air is drawn over the operative area rather than being permitted to descend past the heads of the surgical staff toward the patient. The use of modern filters, plus a ceiling distribution system for continually flushing the room with air free of particles larger than 3  $\mu$  eliminates virtually all airborne bacteria within 3 minutes<sup>47)</sup>.

The effectiveness of a dust-free room in reducing microbiological contamination has been only partially investigated and requires much more study particularly under actual use conditions. Presently it is not possible to predict nor comment on the postoperative clean wound infection rate occurring in the conventional surgery and in the dust-free room surgery.

Each theatre with its adjacent service rooms should have its own adjustable air conditioner easily accessible for maintenance and replacement.

It should be possible to regulate the amount of fresh air entering the theatre and, by means of heating and cooling batteries, to select any temperature within the range 18-30°C, with the relative humidity varying between 40 and 55 per cent, as desired. The temperature of the fresh air should be kept 4 to 5° under the desired working temperature in the theatre. For humidifying, deionized or still water is to be used.

There should be warning devices in the theatre to indicate the state of the filters in the air conditioning system, including a manometer to measure the pressure-drop across the filters and an air flow indicator, both clearly visible in the theatre. Other rooms also with positive air pressure should be equipped with pressure gauges.

Theatre ventilation should be kept running overnight at reduced volumes to prevent reverse circulation in the air ducts.

Before a surgical center is handed over for use the ventilation system should be bacteriologically tested under conditions which simulate normal theatre work.

Where laminar-flow is used around the surgical table the general conditions for a ventilating system could probably be simplified.

The fresh air intake with its screen should be placed as high as possible on the facade. The minimum is about three meters above the ground, but it should be below roof level and preferably facing north. Situations exposed to high wind pressures are to be avoided. The use of a series of filters has

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46) Hughes H G, Starkey D H and Klassen J: Conditionnement de l'air des theatres operatoires par rapport a la lutte contre les infections. 1963, Hospital d'Aujourd'hui 9:1:16-22.

47) Coriell Lewis L, Blakemore William S and McGarrity Gerard J: Medical Applications of Dust-Free Rooms. 1968, JAMA. The Journal of the American Medical Association 203:12:140.

been recommended to remove the outside pathogenic particles over the 10 m $\mu$  range in theatres for general surgery and over the 5 m $\mu$  range in theatres with highest demand on cleanliness.

The use of *ultraviolet radiation* as an agent to suppress airborne bacteria has been recommended. The recommendations include radiation towards the floor at night or when the theatre is unoccupied, and indirect radiation during surgery.

To test the actual influence of ultraviolet theatre irradiation on the incidence of post-operative wound infections a three year study was conducted in the USA <sup>48)</sup>. The study demonstrates that theatre irradiation can reduce the number of bacteria in the atmosphere by more than half and can thus reduce the risk of postoperative infection in clean elective wounds (closed or drained mechanically through the incision or through a separate stab wound). In those wounds that were predisposed to endogenous or pre-operative bacterial contamination the observed incidence of infection was in fact higher following operations under ultraviolet irradiation than it was in an un-irradiated control group. However, the differences were not statistically significant. It was found that many factors influence the incidence of infection to a greater degree than ultraviolet irradiation.

Until these other factors are identified and controlled only minimal benefit, if any, can be expected from the use of irradiation in theatres. Accordingly the investigators discontinued its use.

Bernard, Speers Jr, O'Grady and Shooter <sup>49)</sup> who experimented with closely woven suits have achieved more effective results with ultraviolet irradiation. Bacteria tend to be sheltered from ultraviolet by particles larger than themselves, and the good results achieved with ultraviolet when closely woven suits are worn may spring from a sharp reduction in the shedding of larger particles which break less readily from closely woven cotton.

Various *air sprays, aerosols* and *fogging* have been advocated <sup>50)</sup>. When Körlof <sup>51)</sup> summed up the development in combating airborne infections by the mid-fifties, he stated: the suggested methods were found on critical investigation to be incapable of decreasing the incidence of infection to any great degree. Even the cost and inconvenience of the majority of the methods detract from their practicability under normal conditions.

Also to-day only minimal results might be expected from the use of fogging, air sprays and aerosols.

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48) Postoperative Wound Infections. Report of an ad hoc Committee of the Committee on Trauma. 1964, Annals of Surgery 160:2. Supplement to 2.

49) Bernard H R, Speers Jr R, O'Grady F and Shooter R A: Reduction of dissemination of skin bacteria by modification of operating-room clothing and by ultraviolet irradiation. 1965, The Lancet 2:458-461.

50) cf also Rubbo Sydney D and Gardner Jane F: A Review of Sterilization and Disinfection. Lloyd-Luke Ltd., London 1965, p. 173.

Ewerwahn W J and Kalmar P: Antiseptik im Operationssaal. 1966, Langenbecks Archiv für Klinische Chirurgie. Vol. 316 - Congress report 1966, p. 373-374.

Schmidt-Mende Manfred, Kanz Evald and Thurmayr Rudolf: Untersuchungen über den Staphylokokkengehalt der Luft im Operationssaal und seine Beeinflussung durch Luftdesinfektion. 1968, Brun's Beiträge zur Klinischen Chirurgie 216:2:117.

51) Körlof Bengt. Infection of Burns. 1956. Acta Chirurgica Scandinavica. Suppl. 209, p. 15.

## TECHNICAL SPECIFICATIONS

### Water supply, sanitary equipment

*Hot and cold water* should be supplied to the surgical center at temperatures regulated between 4° and 44°C.

### Water and steam supply

The supply of distilled and sterile water is suitably provided in bottles from a central fluids store, since there are grave risks of contamination inherent in a piped supply. The bottles of water — glass bottles or plastic disposable bottles — are to be sterilized in paper bags, so that they can be delivered to the surgical theatre sterile on the outside.

*Steam* should be piped to the surgical center only if non-electric sterilizers are used.

### Sanitary equipment

Since the nature of work in the surgical center demands a very high standard of hand hygiene the center should be well provided with suitably large *wash basins*. Knee or photoelectric-cell operated automatic mixer taps are recommended as well as aerated streams.

The comfortable working height of the hands can be set at roughly 96 cm, with the water source at approximately 10 cm higher and the height of the basin rim at approximately 91 cm to 96 cm <sup>1)</sup>.

To prevent splashing between basins, screens should be provided at each wash place. Wash places in the form of scrub-up troughs or sloping screens of wired glass minimize splashing.

*Water taps* should be available in the following rooms: theatre disposal room, cleaners' room, plaster room (with plaster trap), pantry, and sterile service.

*Sinks*, wall mounted and with double drainers, will be required primarily in the theatre disposal room, pantry, sterile service and endoscopy (cystoscopy) rooms.

*Water closets* should be wall-mounted and foot operated. Containers for seat protectors should also be provided.

*Floor drains* should be provided only in rooms where water is likely to be upset such as those for endovascular surgery.

### Central piped technical vacuum

*Cleaning facilities* should include vacuum outlets from a central plant situated outside the surgical center.

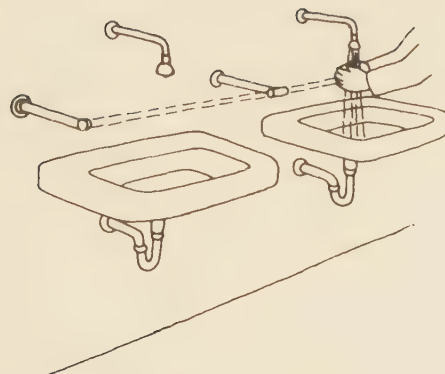
*Refuse removal* can preferably be done by central vacuum<sup>2)</sup>. The refuse is carried in tubes to a separator above an incinerator. There are valves and other arrangements which shut off the refuse chutes from communication

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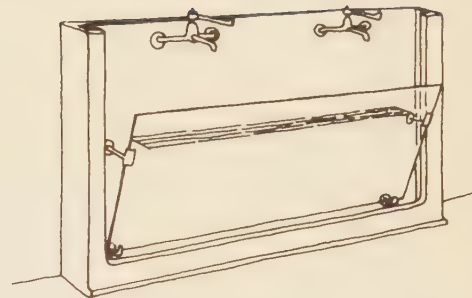
1) Kira Alexander: The bathroom. Criteria for design. Center for housing and environmental studies. Cornell University, Ithaca, New York 1966, p. 16.

2) e.g. system Centralsug, Stockholm.





WASH BASINS WITH PHOTO-ELECTRIC-CELL OPERATED AUTOMATIC MIXER TAPS



SCRUBBING-UP STALLS WITH ANTI-SPLASH APRON

with the vacuum system, except when the vacuum is to convey the refuse to the separator.

A separate tube system can convey *soiled linen* to the soiled linen collecting area.

## Electrical installations

### Plug outlets

It is required that in electrical installations in a surgical center switches, plug outlets, or any other spark emitting appliance using mains current shall be approved and be placed either 1.2 meters above the floor or be so constructed as to meet the security regulations for electrical work in rooms where an explosion risk occurs.

Apart from precautions against explosions, electrical outlets should be so placed that staff are not hindered by leads between wall-outlets and junction-boxes or between junction-boxes and diathermy apparatus, pumps etc.

Loose electric cables must be easily cleaned and must remain undamaged by disinfectants.

All electrical outlets in the vicinity of the operating table may be suitably combined in a control panel comprising main switch, fuse, reostat for endoscopy, signal controls, and plug sockets for mains current and low voltage current for signals and electronic appliances.

The control panel should be placed near the operating table, preferably hanging from the ceiling.

Signal apparatus and wiring must meet security specifications.

In theatres, power requirements have increased significantly. Today about 20 outlets are needed in theatres for advanced surgery.

In the anaesthetic room provision should be made for at least six electric sockets.

In postanaesthetic units, four power-points are necessary for each bed. In postanaesthetic units for cardio-thoracic and similar surgery the requirement is eight.

To meet at least some future development space should be left in building ducts for additional services, particularly electronic audiovisual links.

#### Mains voltage current

Mains current is used primarily for portable X-ray apparatus, suction pumps, and heaters, and secondarily for scouring machines and portable vacuum cleaners if used throughout the center, including the theatres. The theatre therefore should have at least ten main outlets. Grounded outlets in corridors should be spaced at 12-meter intervals.

Electrical circuits in the surgical center, and especially in the theatre, should be complemented with reserve wiring.

Outlets are needed in offices, for desk lamps, and in anaesthetic rooms may be needed for extra illumination during apparatus maintenance work, etc.

Mains current circuits must not interfere with the low voltage circuits.

#### Low voltage circuits    Telephones

Connections to the hospital telephone exchange are needed for offices, duty rooms, changing rooms, and staff lounges. A telephone connection is needed in the theatre for the convenience of the anaesthetist who may have to receive or send messages during long operations.

#### Clocks

Theatre-suite clocks are to be connected to the hospital chronometer system. Each theatre and anaesthetic room should be equipped with a prominent built-in clock with a clearly visible second hand.

#### Photoelectric cell control

Theatre doors and scrub-up room taps can be operated by compressed air devices controlled by photoelectric cell circuit breakers.

#### Electric motors

Allowance should be made for the use of electric motors for maneuvering doors, operating lamps, X-ray apparatus, etc.

#### Acoustic paging, signs, background music etc.

Acoustic paging is necessary in offices, changing rooms, etc., but not in theatres and anaesthetic rooms.

Communication between the surgeon, anaesthetist, and electronic technician outside the theatre, by personal microphones and ear phones, has been considered essential in major cardiac surgery.

Illuminated engaged signs for theatres should be placed in the corridor and may even be combined on a central indicator-board where all electrical apparatus, ventilation pressures etc., can be checked also.

Pleasant background music may be relayed to the surgical center.

## Fire alarm installations

The surgical center should be connected to the hospital central fire alarm system. Advice on the fire-fighting installation proposed should be sought from the local fire authority.

## Generator room for emergency power

Of critical service areas in hospitals in which auxilliary electrical coverage is essential the surgical center, obstetrical suite and the postanaesthetic area come first. A sudden power failure will affect not only heartlung machines and other equipment in the surgical center, but also respirators and monitoring equipment in the postanaesthetic unit.

Theatre lighting, pumps, apparatus, and part of the general lighting system should be connected to the emergency power supply, which, on the failure of normal supply, is switched in automatically within half a second. The switchover to reserve power supply should be indicated on a control panel in the duty engineer's office.

Emergency power for lighting is usually supplied by accumulators, and for other purposes, by diesel motor generators.

## Distribution of medical gases, compressed air and vacuum

Oxygen and nitrous oxide are medical gases used in quantities that economically justify a piped supply. At present it seems unlikely that any other medical gas will be used in equivalent volumes. Sometimes piped breathing air is needed.

## Medical gases

Supply pipes from the central gas store to the rooms where gas is required terminate with stop valves, which, to prevent gas escape, should be self-locking so that gas is only released when an apparatus for administration is connected to the valve.

Outlets for oxygen and nitrous oxide will be needed in all operating theatres, the plaster room, anaesthetic rooms and recovery rooms. Outlets for oxygen only will be needed in the patients' waiting area. Oxygen and compressed air are used in anaesthetic apparatus.

The number of outlets needed in the postanaesthetic area per bed are: one outlet for oxygen, two outlets for suction, and one for compressed air.

Gas outlets are often placed on walls. A preferable arrangement is that gas pipes should be laid in telescopic tubes for compressed air, suction and electrical outlets and possibly monitoring devices also. These telescopic tubes should extend downward from the ceiling to about 2 m above the floor. The installation should be so positioned on the ceiling as to allow flexibility and rearrangement in the placing of the operating table. Depending on the nature of the operating theatre, at least two telescopic tubes per theatre should be positioned around the room.

Only plug-in or similar rapid-connection plugs should be used. Gas connections must be non-interchangeable according to international standards.

## Compressed air, medical vacuum

Special safety measures must be taken to avoid ignition by electrical sparks or heat of the combustible matters in an eventual oxygen atmosphere in case of leakage in the oxygen or nitrous oxide tubes or valves.

The use of pneumatic motors for medical and other purposes, suction pumps, respirators, surgical equipment and the like, may require the installation of central compressors. At least two suction outlets in a theatre should be provided.

Compressed air must be clean and dry. The compressor air-intake should therefore be provided with a filter and placed where there is a sure supply of uncontaminated air. To obtain a reserve of air and a drying effect simultaneously, the compressor can be used to fill an air-tank. This reserve gives a certain safety margin during power failures.

The installation must not be placed in the same room as the oxygen and nitrous oxide containers.

To avoid confusion, compressed air pipes are to be coloured according to national standards. Outlets also must be peculiar to the system.

Compressed-air pipes must be laid to fall, and arrangements must be made for drawing off condensation moisture.

Pneumatic injector suction pumps with a sealed extract to isolate infected air are considered most suitable. They can be supplied either from a central installation or from local compressed-air tubes.

Surgical suction devices, besides injector pumps, comprise water-jet pumps and mobile electric suction pumps.

A central vacuum installation to serve the entire hospital may be considered as a good alternative.



The main aim when planning the surgical center is to create proper working conditions for the medical staff and to contribute towards avoiding wound infection.

Planning measures for the prevention of infection should be based on knowledge of all sources and mechanisms of the infection as one component in a wider pattern of defences against hospital infection.

If the mechanism of factors influencing wound sepsis were thoroughly understood, wound sepsis as such would probably be made extinct. The present state of our knowledge is not such. There is still no clear, authoritative voice to state the cause of postoperative wound infection and how it can be prevented. All decisions made are still based on imperfect data.

The postoperative infections must arise from the interaction of the strains of pathogenic organisms that are present at any time with human carriers on the one hand and with susceptible patients on the other. It has long been known that most surgical wounds are contaminated to some degree with bacteria, but that few become infected. There is still little known about the determinants of these infections.

At the present time workers studying the aetiology of postoperative infection represent different conclusions and stress different aspects, and thus support the natural view that several factors may be instrumental. The general and local resistance of the patient, the virulence and size of inoculum of the contaminating organism and a host of other yet poorly understood factors determine whether infection will occur. In addition, these elements vary irregularly and widely from time to time and from place to place, as do the opportunities afforded by the environment for the physical transfer of the pathogenic substance, whether by tactile contact or even by air.

Most studies in postoperative wound infections have been directed toward the investigation of factors which influence the bacterial environment in which operative procedures are carried out (the inoculum). In spite of that an increasing number of studies suggest that local factors in the wound (the medium) more significantly influence the incidence of wound infection than does the inoculum.

Although indication is growing that for a great part of postoperative wound infections events in the surgical theatre are *not* at fault, for the time being the main factor generating postoperative wound infections is considered to be the human element, the behaviour of the staff at the time of operation, seconded by the endogenous agents.

There is a general agreement that the tactile contamination is of the utmost importance. This requires the aseptic technique to be strictly observed, although some procedures in the basic operation routine (e.g. preoperative showers for the staff, changing underclothes before operating, using of fat solvents in routine disinfection of the skin, use of tacky mats and disinfectant mats in doorways, use of theatre trolleys with retractable wheels <sup>1)</sup>) believed to support the aseptic technique could probably be simplified or discontinued.

The present routines have in themselves a tremendous importance as pedagogic instruments pointing constantly towards the need of aseptic and technical perfection in performing the operation.

*It must be emphasized very strongly that whatever structural and technical precautions may be taken, it is the attitude of the staff to asepsis particularly and hospital hygiene generally which determine the standards maintained within the surgical center.*

Air studies to date do prove that infectious agents can be recovered from the air and that filtration and ventilation methods can greatly reduce the number of such agents. However, these studies rarely prove or even demonstrate a connection between a known case of infection and the presence of a pathogenic organism.

The assessment of the absolute and relative significance of the environment as a contributing factor towards the infection in the patient is still obscure.

In particular the role of air in wound sepsis must yet remain speculative. This conclusion requires a more modified view on ingenious ventilation arrangements in units for general surgery. At the same time it is not meant to imply that efforts in reducing the bacterial flora in surgical suites where sterility is the prime condition for success are without merit.

A high standard of air cleanliness is important, but it is becoming increasingly evident that it is much more important that efforts should be concentrated on eliminating opportunities for tactile transmission and that there is a disciplined adherence to strict aseptic technique when dealing with wounds as well as a strict traffic control in operating rooms.

Although people rather than things are the chief postoperative sepsis problem, the environmental approach cannot be ignored. The control of movement of staff, patients, objects and to some extent air along broadly planned routes should be regarded as a correct principle. The planning should be aimed at the influencing of the conduct and attention of the staff by careful adaptation of architectural means. The design may assist the surgical team in carrying out aseptic technique or make it difficult,

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1) cf also Aseptic methods in the operating suite. 1968, The Lancet 2:831.

even impossible. Two basic requirements obtain in all situations: a strictly observed regime and control of personnel within the area involved to prevent dissemination of pathogenic micro-organisms and the immediate disposal of all waste and used supplies.

When the precautions which the surgeon and his staff have to observe become so stringent as to restrain surgery, the sepsis risk must be weighed against any possible detriment to the patient. Designs which endeavour to control infection by very greatly increased discipline may produce resentment in the staff thus resulting in a detrimental rather than a beneficial effect on the problem.

One of the ways in achieving the control of staff by architectural means is by separating different groups of traffic and by zoning the center. This probably helps to reduce the human errors of the staff and deviations from the aseptic routine, even if this belief cannot be backed up in any way by precise observations. This refinement in architectural principle is probably only marginal. It is still more likely that it never could be evaluated.

As our knowledge of the aetiology of bacterial infection improves it may be found that many of the present elaborations do not provide advantages and plans may become simpler.

It has been said: In architecture, there are no spectators: there are only participants <sup>2)</sup>. However, regarding the individual's comprehension of spatial qualities, extremely little is known about the role played by any other aspect of the room than its physical proportions <sup>3)</sup>.

In a theatre, colours, sounds, smells and textures tend to become sharpened, gain special significance and give more outspoken sensory motion. An emotional part in medical building design that is not relevant in some building types is the aim to create for both the patients and the staff a sphere of outspoken warmth and dignity.

Whatever the season or the weather, the conditions that promote the comfort of both surgical team and patient are to be maintained. In a surgical theatre the aim is to create conditions which are apparently favourable during operations lasting about six hours and meet all the body's requirements.

To-day many man-made environments seem not to satisfy the full environmental specification required for complete human beings, as the

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2) Fitch James Marston: The Aesthetics of Function. 1965, Annals of the New York Academy of Sciences 128:706.

3) cf also Thiberg Sven: The determination of dimensions by full-scale laboratory tests. Report 46:1968, The National Swedish Institute for Building Research, Stockholm 1968, p. 15.



current approach in relation to the thermal environment is to think in terms of placing the human body in conditions of thermal neutrality and in the case of visual environment, to provide conditions of uniform illumination. Both these approaches seem to be very debatable and have been discussed by Kendrick <sup>4)</sup>.

The concept of so called optimum conditions for physical environment as implying some fixed set of environmental conditions for so called perfect comfort seems to be suspect, because it is known that a minor change of temperature, humidity, air movement, illumination or other physical factor away from the middle of the comfort range will check any feelings of monotony and thus will act in a beneficial manner. Variety is not the spice of man's natural life, it is the very staff of it <sup>5)</sup>.

On that basis optimum conditions could perhaps be considered as a set of tolerable variable oscillators in the range of environmental conditions, with the conditions changing and operating at random to provide stimulation and variety in physical environment.

The interrelationship between the various environmental factors as they affect the human being is under discussion. There is a known subjective response to the interaction between some aspects of the physical environment factors: the various combinations of air movement, temperature, relative humidity and radiation influence the thermal comfort. It is not known whether people need a different thermal environment in a dark room and in a light room, or in rooms with different colour schemes, or in a noisy room compared with a quiet one.

At a fundamental level it is not known how far it is possible to compensate for a loss in one environmental factor by increasing the effect of another, and whether or not this can apply to all physical environmental factors.

The suggested values of the main features of the multisensory environment discussed in earlier sections should be regarded as median values.

An important factor in briefing and planning procedures is the identification of a trend in medical development, likely to cover a time span of at least ten years.

The future may be inferred from the experience of the past through the expectation, or at least the hope, that certain situations and actions will tomorrow result in effects similar to those which they produced yester-

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4) Kendrick J D: Human factors affecting design of physical environments in buildings. 1967, The Medical Journal of Australia 2:267-269.

5) Woodburn Heron: The Pathology of Boredom. 1967, Scientific American 196:1:52.



day. Our expectation may also be based on an intuitive sense of the way things might happen; or it may be derived from a comprehensive theory of the inevitability of change. Future events, however, very seldom develop in exactly the way one has foreseen, whatever the method of prognostication has been.

Since the scientific philosophers of the post-Darwinian period the in-absoluteness of truth and temporary validity of knowledge has been emphasized. Change can be regarded as one of the few constant factors in the life process.

Experience of medical prognoses is limited and generally disappointing. The studies of Biörck <sup>6)</sup> seem to confirm that both the prophecies and the events have been of a modest order. There have been rapid developments in sectors which were hardly mentioned or even wholly neglected. This has particularly been the case with technical development, both generally and within the medical field.

It is assumed that a high percentage of the surgical knowledge today will be obsolete in ten years as this knowledge will most likely be roughly doubled and that much of the surgery of the next decade is still in the experimental stages today.

New medical specialities will come into being in the interfaces between existing disciplines, currently integrating their activities to vitalize attacks upon mutual problems.

In surgery and its related activities, human and other factors which are not so readily measurable must take precedence over any mathematical calculations. A fancyfree and rigidly categorical transferring of overdetailed time and motion studies without adding any trend in future development to routines can only result in shortlived arrangements. The more refined and analytic instruments used, the more situationsbound and development-resistant the proposed routines will be.

Most likely a surgical center which imposes a fixed pattern of work on those who use it, not matter how theoretically excellent at the time of conception, is in practice less useful than the one which may be used in a variety of ways <sup>7)</sup>.

Re-evaluation and re-definition of the total activities in the present surgical program as well as automation and mechanical devices may release personnel to other tasks and influence the need for operating theatres and overall average times in the surgical center. The increasing role of outpatient

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6) Biörck Gunnar: Medicinska utvecklingslinjer och framtidens sjukvårdsorganisation. 1953, Svenska Läkartidningen 49:1057-1071 and Om tio år . . . 1965, Läkartidningen 62:21-31.

7) cf also: Nuffield Provincial Hospital Trust. Studies in the Functions and Design of Hospitals. Oxford University Press. London, New York, Toronto 1955, p. 90.

surgery should be mentioned particularly. It is believed that such practice is entirely safe, indeed, safer than many inpatient practices, if it is undertaken seriously and with rigid controls by the surgeon and the anaesthetologist.

When designing a surgical center the problem is to provide adequate spatial facilities for a basic procedure which has both functional and dysfunctional components. The functional side — the surgery itself — seems to be most stabilized, even prognostically<sup>8)</sup>. Anaesthetic techniques are likely to change sooner. The quite dominant dysfunctional side — connected with aseptic technique — may be rather profoundly changed in the sector of environmental control, and particularly in the sector of background contaminants.

There is conflict between complex and fluid processing systems and the rigidities of environmental setting and structures, the transitory process cannot be met in structures conceived as final architectural statements. So the problem is how to harness an organization which has a rate of growth or change so rapid that its buildings become obsolescent before they can decay naturally<sup>9)</sup>.

The curve of organizational growth is exponential — very roughly S-shaped. An initial period of slow growth is followed by a period of quite rapid expansion which gives way to a long period showing almost no increase<sup>10)</sup>. Developments along the rising S-curve are of the greatest interest. Very often it is believed that the rapid expansion will continue for some time. If the change to the final, quiet stage occurs too soon or too late, considerable trouble may arise. The growth may also be irregular and spasmodic, and growth in one place may be accompanied by decay in another<sup>11)</sup>.

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8) With the intensive research going on throughout the world, the major progress in surgery during the next ten years will with the greatest probability be in the field of transplantation surgery.

As a device to make the conventional scalpel obsolete, the biomedical laser is a device found in today's medical research laboratories. So far the medical laser has proven operationally feasible in very few areas, e.g. ophthalmologic photocoagulation. In most areas the laser has not yet graduated from experimental surgery. Neither as a general surgical instrument nor as a source of significant nonocular trauma does the laser now seem worthy of consideration by the general surgical clinician.

Another new technique — cryosurgery — is based on liquid nitrogen at a very low temperature. Nitrogen is brought into contact with diseased tissue through a hollow probe, the tissue briefly exposed to freezing later dies and sloughs away. Even this cold knife is quite far away from widespread application.

9) Weeks John: Indeterminate Architecture. Transactions Bartlett Society. Vol. 2. London 1965, p. 85-106.

10) cf also Medawar Peter Brian: Size, Shape and Age. in Essays on Growth and Form. ed by Le Gros Clard and Medawar. Clarendon Press, Oxford 1945, p. 157-186.

11) Weeks John: Paper on »New Developments in Hospital Design and Construction» for conference of Institute of Hospital Administrators. London May 26th 1959.

Structural problems of growing architecture have been observed for some time. There are two basic methods of meeting the needs of potential functional and spatial change: either by following the requirements of indeterminate architecture or by total replacement within an existing organization, with all traffic and transport connections preserved.

The requirements of indeterminate architecture as stated by Weeks <sup>12)</sup> are: The plan should enable each zone to expand at different rates, the internal street pattern should be designed for systematic extension, the structural system extensible and the service system universal.

The architectural structure has a limitation in its quantitative growth, the extent of the limitation depends on the weakest sector. Adaptable internal building systems may eliminate or reduce many of the disadvantages of conventional renovation methods.

The total replacement by keeping a proper place in the organization with all transport and traffic connections preserved follows the Ise shrine <sup>13)</sup> idea, where every twenty years the buildings and their enclosures are in a slightly modified form rebuilt on an adjoining site, thus taking advance of the preserved basic situation. When the new buildings have been consecrated and the symbols in which the deity resides have been installed the old buildings and fences will be dismantled.

The time factor should be considered very carefully, not least when determining the relationship between planning and building periods and the short economic life of a hospital. As the rates of change, growth and decay are quite different for different components, the process follows a very complicated pattern. A clarification of the mechanism of this process would contribute more towards a more economic building <sup>14)</sup>.

Cowan <sup>15)</sup> has estimated the economic life of a hospital somewhere between 40 and 50 years, basing this on depreciation rates. Probably today this length of time should be maximised to 40 years. Equipment and installations deteriorate more quickly than the structure — in 15 to 20 years <sup>16)</sup>.

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12) Weeks John: Hospitals for the 1970's. Reprinted from the Journal of the Royal Institute of British Architects for December 1964, p. 3.

13) Drexler Arthur: The Architecture of Japan. The Museum of Modern Art. New York 1955, p. 23 ff.

14) Pütsep Ervin: Strödda anteckningar kring sjukhusplanering. Svenska sjukhusföreningens årsbok 1965, p. 113-122.

15) Cowan Peter: Studies in the Growth, Change and Ageing of Buildings. The Transactions of the Bartlett Society 1962-63. The Bartlett School of Architecture. University College. London 1964, p. 70.

16) cf also World Resources Inventory. Southern Illinois University: Human trends and needs. Carbondale. Ill. 1963, 22.

The design and furnishings of surgical suites in developing communities will be influenced by limitation of available funds and trained personnel. Elaborate monitoring devices are frequently beyond the budgetary capacity of these surgical services. Proper repair and maintenance of complicated or electronic equipment is likewise not always feasible. With proper selection and carefully supervised on-the-job-training non-professional individuals can be made to serve as reliable human monitoring systems <sup>17)</sup>.

It is vital that the creation of a surgical service in developing regions be initiated on a relatively modest scale and be allowed to grow in size and function, rather than being on a sizeable scale and face operational stalemate.

A slow start will permit correct assessment of local surgical needs as well as proper sizing up of functional possibilities. It will also allow the personnel to realize the aims of the venture, and make the required behavioral adjustment. A drastic imposition of new ideas does not always give the desired results.

Deficiency of material can at times be made less frustrating by simplification of technique and on-the-spot innovations. Despite the rapidly expanding market of complicated surgical appliances and products, it is still possible to practise sound surgery with simple basic tools.

Many of the so called surgical rules are results of the cumulative experience of surgeons based on a series of surgical situations. Few of these are inviolable biological laws <sup>18)</sup>, and there is always a possibility of further experimentation and development.

Dangerous compromise with established and proven principles of wound management can hardly be advocated. But Western notions of cleanliness are not necessarily synonymous with best hygiene in all instances <sup>19)</sup>.

What may appear to be a gross infringement upon surgical rules in a well equipped and well staffed university hospital in Northern Europe or America, may still be an acceptable surgical practice in some of the under-staffed, poorly equipped and overcrowded surgical services in the emerging countries.

The results of aseptic technique remain dependent upon the proper comprehension of principles and conscientious implementation of them by each individual on the staff from the auxiliary worker to the chief of the particular surgical center.

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17) personal communication: Farrokh Saidi MD, Shiraz.

18) Haley Jr H B: Surgical Principles. 1965, Surgery, Gynecology & Obstetrics 120:820.

19) Cultural Patterns and Technical Change. ed by Margaret Mead. A Mentor Book. 1955 UNESCO. 9th printing, p. 224-228.



Architecture is the synthesis of the *art* of design and the *science* of determining principles which guide the design process. The building is always the expression of time-bound creative ambitions. Today, more than ever before, these ambitions must be disciplined by objectively verifiable terms of reference. Some decisions still have to be made on assumptions and guesses on a basis of fragmentary material. The final form of the design is, however, very greatly determined by the order in which the components are considered. Every decision leads to a special kind of order.



## SUMMARY

Attempt has been made to study the various elements conditioning the current requirements and opinions for safe surgery. A broad outline, adjusted to the horizon of a hospital planner, has been given.

Neither architectural design nor mechanical equipment, nor even operating management can hope to influence the endogenous factors in the complexity of the wound infection. Surgical theatres cannot be designed to provide a panacea against any eventuality.

When planning the surgical center a multisensory approach is recommended towards the environmental control.

Spatial requirements for all other functions controlled with a surgical center have been discussed as well as some aspects of technical installations and equipment.

In planning, ways and means to permit growth and change in an orderly fashion without disturbing the internal organization must be anticipated. Planning which is highly specific, rigid and fulfills only a strictly limited function must curb the future use of the building. This is most important in circumstances where changes in function are to be expected.

## APPENDIX: DETERMINING THE NUMBER OF OPERATING THEATRES

For a long time determining the number of operating theatres required in a general hospital or surgical center has been empirical. It has been thought for example that approximately one hour's operating time was required per bed per week, or that the number of theatres was related to the number of hospital beds, particularly surgical beds.

Thus Gohrbandt <sup>1)</sup> recommended a quota of one theatre per 50-70 beds, Karman <sup>2)</sup> and the U.S. Surgeon General <sup>3)</sup> suggested one theatre per 50 surgical beds. For a hospital with general surgical, gynaecological and orthopaedic department Pütsep, Thorp and Goldring <sup>4)</sup> suggested as appropriate a maximum of 40 beds per theatre. Newcastle Regional Hospital Board <sup>5)</sup> and Blowers <sup>6)</sup> have arrived at the same figure.

Where the proportion of lengthy operations is greater a value of 25-30 beds per theatre was suggested by Pütsep, Thorp and Goldring <sup>4)</sup>. Walker and Douglas <sup>7)</sup> suggested in such connection a quota of 30 beds per theatre.

One theatre for every 25 surgical beds seemed to be a reasonable target for Hume <sup>8)</sup>. According to Sellors <sup>9)</sup> a firm with two surgeons who use 50 to 60 beds should have two operating theatres at their disposal.

Labryga <sup>10)</sup> has recommended for 100 surgical and 30 gynaecological beds, three operating theatres.

Poelzig and Meyer <sup>11)</sup> recommended one theatre for three major or four to five minor operations a day.

The provision of endoscopy, cystoscopy and plaster rooms and theatres in Casualty and Out-patient departments would be additional to the figures stated above.

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- 1) in Vogler P and Hassenpflug G: Handbuch für den neuen Krankenhausbau. Urban & Schwarzenberg. Munich - Berlin 1951, p. 194.
  - 2) Karman Jarbas B: Cirurgia. in Planejamento de Hospitais. Sao Paulo 1954, p. 180.
  - 3) Public Health Service Regulations. Part 53, Appendix A. General Standards of Construction and Equipment. Revised Jan. 5th, 1955.
  - 4) Pütsep E, Thorp J and Goldring C: Om operationsavdelningar. Centrala sjukvårdsberedningen, P 15, Stockholm 1962, p. 40.
  - 5) Newcastle Regional Hospital Board. Report of the working party set up to consider general principles regarding requirements in operating suites. Newcastle 1964, p. 8.
  - 6) Blowers Robert: Hospital Infection. in Clinical Surgery. General Principles and Breast. Ed by Charles Rob and Rodney Smith. Butterworths. London 1964, p. 33.
  - 7) Walker W F and Douglas D M: The surgeon's angle on the operating room. in Operating Theatres and Ancillary Rooms, ed by T Cecil Gray and John Nunn. John Sherrat and Son. Altrincham 1964, p. 153.
  - 8) Hume K F: The operating theatre designed for the surgeon. 1965, Hospitals' Association Journal 34:6:14.
  - 9) Sir Thomas Holmes Sellors: The Planning of Operating Theatres. 1963, Proceedings of the Royal Society of Medicine 56:8:733.
  - 10) Labryga F: Krankenhaus der Grundversorgung. 1968, Medizinal Markt 16:80.
  - 11) Poelzig Peter and Meyer H W: Programmierung eines modernen Akutkrankenhauses. in Neue Krankenhäuser in Nordrhein-Westfalen. ed by Max L R Reisinger, Peter Steffen and Josef Marke. Verlag Paul Geyer OHG. Cologne 1966, p. 35.



The size of the surgical center may be more exactly calculated when the number of theatres is related to the following factors:

- the number of surgical and equivalent beds
- the percentage rate of bed occupancy
- the average stay for patients in surgical and equivalent departments
- the length of the operating period
- the hygienic standard, which may be equated with the time needed for theatre resting and cleaning.

$$\text{the number of theatres required} = \frac{\text{total number of operations per year}}{\text{number of operations that should be performed in one theatre per year.}}$$

A fairly accurate estimate of the number of operations to be performed per year is achieved by using the formula:

$$\text{number of operations} = \frac{\text{number of surgical beds} \times 365 \times \text{percentage of bed occupancy}}{\text{average length of patient stay} \times 100}$$

By using the average percentage of the three busiest months both for bed occupancy and length of stay rather than the annual rates, most of the influence of seasonal variations may be eliminated.

Today the duration of surgical convalescence seems to be very largely unpredictable <sup>12)</sup>. Identifying the factors that determine the current unpredictability may result in considerably shortened length of stay and thus an increase in the number of possible operations.

The next step would be the determination of the average number of operations which should be performed in one theatre in one year.

The number of normal operating hours per annum per theatre would be at most 1500 (250 normal operating days, maximum 6 hours a day) including emergencies.

Extending the operating day beyond the suggested six-hour period for the in-patients has been discussed. There seems to be a predominant feeling that preparation procedures late in the day may create considerable psychological anxiety and with an extended operating schedule the patient would have to go without food for an unnecessarily long period of time.

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12) cf also Kolouch Fred T: Computer Shows How Patient Stays Vary. 1965, The Modern Hospital 105:5:130-134.

Average times in minutes per operation which have been recorded show considerable variations. The times found by Cowan <sup>13)</sup> appear in the following table:

|                 |    |             |    |              |     |
|-----------------|----|-------------|----|--------------|-----|
| general surgery | 39 | ENT         | 27 | thoracic     | 116 |
| gynaecological  | 47 | orthopaedic | 38 | neurological | 182 |
| eye             | 35 | urological  | 67 | dental       | 30  |

Cowan <sup>13)</sup> has suggested 50 minutes as a reasonable time per actual operation. Allowing 40 minutes as a reasonable interval between operations, the result is a total average of 90 minutes per operation in a general hospital.

In a Swedish survey <sup>14)</sup> 144 surgical operations have been analysed and an overall time — as recorded by the anaesthetist — of 65 minutes per operation was established. The surgeon's view on the length of operations in the same connection was different and recorded as 97 minutes. Whitson <sup>15)</sup> recorded as the average surgical time per procedure 50 minutes. Polk Jr <sup>16)</sup> has recorded as average duration for celiotomy 99 minutes, and Lindbom, Laurell and Grenvik <sup>17)</sup> for thoracic surgery 200 minutes.

As concluded from the available evidence Cowan's overall average could still be regarded as satisfactory for the present time and used in calculating the number of theatres needed.

The number of operations that could be performed in one theatre per annum is thus  $\frac{1500}{1.5}$  or 1,000. E.g. in a hospital with the estimated number 10,600 operations to be performed over a period of one year the number of theatres required would be  $\frac{10,600}{1,000} = 11$ . One of the operating rooms is expected to be always available for emergency cases.

In order to arrive at a correct final figure all factors in the formula for the number of operations as well as the factors determining the number of normal operating hours should be carefully considered.

*Until more clear-cut tendencies emerge the presented formulas could be used.*

13) Cowan David: A method for estimating the number of operating theatres required in a general hospital. Council for Scientific and Industrial Research. Report No. 201. Pretoria 1963, p. 4.

14) Arbetsförhållanden för läkare vid Sahlgrenska sjukhuset. 1965, Sjukhus 42:272-281.

15) Whitson C Wilson: A Queuing Approach to Staffing the Operating Room. In Hospital Industrial Engineering. ed by Harold E Smalley and John R Freeman. Reinhold Publishing Corporation. New York 1966, p. 350.

16) Polk Jr Hiram C: Surgical Skin Preparation. A Clinical Comparison of Two Methods. 1967, The American Surgeon 33:209-212.

17) Lindbom Gunnar, Laurell Gunnar and Grenvik Åke: Studies on the epidemiology of staphylococcal infections. 3. Influence of Factors Inherent in the Patient and his Operation. 1967, Acta Pathologica et Microbiologica Scandinavica 69:219.

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